DEVELOPMENT OF HYDROELECTRIC POWER IN BRAZIL

Isabel Tessa Kilvington

Ph.D.

University of Edinburgh

1983

ABSTRACT

Brazil is a large country which has been in a process of extensive industrialisation since the Second World War. Industrialisation requires an abundant and reliable supply of electrical energy, and Brazil has depended on its long tradition of utilisation of hydroelectricity in order to guarantee this necessary power supply.

As the hydraulic sites close to the industrial centres have become fully exploited, Brazil has had to turn to more distant regions for hydroelectric power development, thus requiring long distance transmission of large blocks of electricity. This has led to the construction of some of the world's largest hydroelectric power stations, such as UHE Itaipu and UHE Tucurui, in some of the most isolated and inhospitable places on earth, with their attendant problems in construction and project co-ordination. Not for the first time is Brazilian hydroelectric power development taking place simultaneously with technological and advancement - at present, in the field of long distance transmission. However, it is, for the first time encountering the problems of international power sharing.

The lessons to be learnt from Brazil's most recent experiences in large scale hydroelectric power development are mainly relevant to its own future projects, but some general lessons are applicable to such developments in other regions of the world.

DECLARATION

I declare that this thesis has been composed by myself and that the work contained within it is my own.

September 1983

ACKNOWLEDGEMENTS

With thanks to the late Harold Dickinson and Peter Dryburgh for their help and encouragement.

A thank you is also given to those many people, both in Edinburgh and Brazil for their co-operation and friendship throughout the period of study. Lastly thanks are given for the constant support and encouragement from my mother and late father - to whom this thesis is dedicated.

CONTENTS

FIGURES

TABLES

CHAPTER 1

Introduction

Literature Survey

The published literature on Brazil is extensive. The bulk of it is, however, published within Brazil and remains untranslated from the original Portuguese. Certain topics have attracted considerable foreign interest. Of these the best known are the vastness of the Amazon Basin, with its particular human and environmental features, and Brazilian development, both from the point of view of its heroic proportions and the intensity of the poverty in the North East of the country.

To turn to the specific subject of this thesis, it is soon observed that the literature on the power industry in Brazil, in the English language, is sparse. There are a few, short, articles but no comprehensive review of the industry and its growth. The nearest is "Electric Power in Brazil : Entrepreneurship in the Public Sector" by Judith Tendler,(1968). This is a detailed study of the battle of the private companies within the electrical power industry, and its effect on Brazilian economic development(1).

When the literature search was extended to Brazil, access to libraries was readily granted, but it was soon found that their collections were of a variable standard and less than comprehensive, especially with respect to journal collections, which were often incomplete or not up to date. The main exception to this was the library at the Centro de Pesquisas de Energia Eléctrica (CEPEL), which, although new, was comprehensive and well organized. Much of the useful documentation was found to be in the form of internal reports, and access to such documents depended largely on personal goodwill on the part of the librarians and other officials of the organizations visited. The majority of requests for material were acceded to and, as a result, the literature base of this thesis forms the largest collection of unique material available in the United Kingdom. However, as with all collections of documents, there are inevitable gaps where information was not made available due to its confidentiality.

A brief survey of the literature available, which has a bearing on the Brazilian electrical power industry, together with a longer section on water resources development for power production, is given below.

Brazil - General

For a good general introduction to those aspects of Brazil broadly associated with the development of the country, in an overall sense, the publications by the Foreign Service of the Brazilian Embassy in London (now discontinued) give an adequately detailed introduction. Factually correct, although sometimes over optimistic, they give a reasonable insight into the country (2-16). These publications cover all aspects of Brazilian society and organization, including the roles of the Church and the State, inflation and economic growth, foreign policy, resources, communications and energy. Within this series of publications, No.14, "Brazil-A Geography" contains a short bibliography of those books which give a good insight into the way in which Brazilian development has proceeded.

Important general books published in the United Kingdom include "Brazil" by J.P.Dickenson (1978)(17), "Brazil-A Giant Stirs" by R.P.Momsen (1968)(18), and "Brazil : A Political Analysis" by P.Flynn (1978)(19). The more substantial nespapers are good sources of up-to-date information, in particular The Financial Times regularly prepares reports on Brazil which comment extensively on large scale resource exploitation, financial problems and the status of industry (20-26). The Brazilian newspapers are useful for data acquisition and for a Brazilian view of events. The runs of local papers consulted included "Journal do Brasil"(27),"Folho de São Paulo"(28) and "O Globo"(29); on the whole they were well written and informative.

Statistical information is available from the publications of the Instituto Brasileiro do Geografia e Estatística (IBGE), which publishes the national censuses(30), as well as a wide range of informatory books, maps and pamphlets. The United Nations Statistical Handbooks also contain much useful information(31).

<u>Brazil - Development and Economics</u>

Development and economics problems are the aspects of Brazil which generate the most interest for research workers. The best known translated works are, probably, "Development and Underdevelopment" by the Brazilian, Celso Furtado (1964)(32), and his later work "Economic Development in Latin America"(1970)(33). The three National Development Plans give the best insight into the Brazilian views of the needs and intentions of development(34-36). Many works concentrate on the adverse side of economic development, such as "São Paulo:Growth and Poverty" published by C.I.I.R.(1978)(37), "Irrigation in the Brazilian North-East :Anti-Drought or Anti-Peasant" by A.Hall(undated)(38). Others hold up Brazil as an example to the Third World, and are typified by an anonymous article in the Brazilian journal Comércio e Mercados "Terceiro mundo tem no Brasil um exemplo de desenvolvimento"(1973)(39).Many of the available publications deal with the direct relationship between Brazil's economy and industry, politics, or inflation. These include "The Brazilian Industrial Economy" by W.G. Tyler(1981) which is the most recent(40), and "Inflation and Economic Development in Brazil, 1946-1963" by R.Kahil (1973)(41). A number of Brazilian journals such as "Comércio e Mercados" (42) and "Planejamento e Desenvolvimento"(43) proved useful in obtaining an insight into the current Brazilian views.

Brazil - Energy

In Brazil, energy has been regarded as a great force behind the country's development (see p.26). Increasing use of electrical energy has been hailed as a great indicator of economic progress(44),and the National Development Plans have all outlined energy developments(45-47). Due to the great hydraulic resources available increased hydropower is regarded as a mark of progress, as in, "Ilha Solteira : um marco do progresso", Energia Elétrica (1979)(48). However, the lack of indigenous oil and coal are seen as slowing Brazil's development, see, for example, "Inflação no Brasil e a OPEP de 1980" by P.Cotta(1980)(49). In Brazil, the result of the world oil crisis has stimulated the alcohol substitution programme(50) and increased interest in nuclear power(51). It is almost impossible , however, to find out details of Brazil's attitudes and plans in the latter respect. It is a very politically emotive subject, and even within the state utility, Empresas Nucleares Brasileiras S.A. (NUCLEBRÁS), there is little information given to the employees(52).

The bulk of the information generally available in Brazil on the topic of energy, particularly of hydraulic origin, is contained in a number of specialised journals. The most important of these is "Mundo Elétrico(53) which publishes articles on all aspects of Brazilian power. "Construção Pesada"(54), a mainly civil engineering journal, prints articles on various large dams under construction in Brazil, with a number of special issues on Usina Hidrelétrica Itaipu (UHE Itaipu). "The Revista Brasileira de Energia Elétrica"(55), produced by the government utility Centrais Elétricas Brasileiras (ELETROBRÁS), now no longer published , not only described the work of ELETROBRÁS but also appraised the organization and its aims, and those of the electrical power industry in general. A number of other journals are also useful in providing occasional information, including "Relatório Reservado"(56), "Revista do Clube de Engenharia"(57), and "Energia Elétrica"(58).

On many aspects of the power industry, the only information available was from personal interviews and private reports generated within government departments and ELETROBRÁS . Amongst these may be included the report prepared by the Canambra Engineering Consultants Ltd.(CANAMBRA)(1966 & 1969)(59,60), the Plano de Atendimento dos Requisitos de Energia Elétrica até 1990 (Plano 90)(1974)(61), the Plano de Atendimento aos Requisitos de Energia Elétrica (Plano 95)(1979)(62), the Tucuruí (Estudos Basicos) report (1972)(63) and the 1980 plans of the Grupo Coordenador de Operação Interligada (GCOI)(64).

The best comprehensive books available in Brazil are a special edition of Mundo Elétrico "Setenta e cinco anos de energia elétrica no Brasil"(1976) (65) and "A Energia Elétrica no Brasil"(1977) published by the Biblioteca do Exército Editora (the army publishing house)(66). Each of these gives a good review of the historical development of the electrical power industry in Brazil, and were used as a basis for much of the work in Chapter 3. Other sources of data were supplied from the various end-of-year reports published by the electrical power utilities in Brazil , such as ELETROBRÁS, Centrais Elétricas de Furnas (FURNAS) and Centrais Elétricas de São Paulo S.A.(CESP), as well as the public relations documentation which these organizations were always willing to hand out.

The easiest subject on which to obtain material was UHE Itaipu*, which is to be the the largest hydroelectric power station in the world. However, much of it proved repetitive (it is a popular topic and there is little new to say about it). In consequence, UHE Itaipu was no longer a topic requiring further study, unlike UHE Tucuruí which, because it has never been effectively documented, was chosen as a case study for the purpose of this thesis.

As mentioned above, Tendler(1968) provides an excellent guide to the economics of the Brazilian electrical power industry in the 1950s and 1960s. Civil engineering details of various Brazilian dams are published in International Water Power and Dam Construction(68), and historical details are occasionally to be found in the Proceedings

* UHE - Usina Hidrelétrica, is the Brazilian acronym used to denote a hydroelectric power station, and has been adopted here in order to maintain clear differentiation between hydroelectric power stations, construction sites and companies. UTE - Usina Termelétrica has similarly been adopted to denote thermal power stations.

and Journals of the Institution of Electrical Engineers (London) and the Institute of Civil Engineers (London)(69,70). Such material is limited, as most participatory interest in the early Brazilian power industry was American or Canadian, and very little was recorded in the British journals. In addition, except for international conferences, most Brazilians publish in their own national journals.

Water Resources Development for Power

When water resources are developed for the production of power, it usually means that a river is dammed or diverted. When this happens there is a great impact, not only in the area adjacent to the dam and its impounded waters, but often hundreds of kilometres distant. For example, with all of the schemes discussed in this thesis the construction of a dam across a river has resulted in the creation of a man-made lake, often inundating many hectares of land. When a river is dammed with the explicit purpose of producing electricity, many of the other possible uses for the man-made lake, such as flood control, irrigation, navigation, urban water supply and waste disposal are largely ignored.

Whatever the advantages and disadvantages of building a dam for the provision of hydroelectric power, the impact of the dam will be felt in the distant areas where the power is consumed; downstream of the dam; upstream in the upper parts of the watershed; in particular, in the region of inundation; and throughout the economic and political life of the nation(s).(71)

In the "Third World" such dams, and reservoirs, are responsible for the provision of electricity and improved living standards for city dwellers(72), loss of homes(73), and culture for rural peoples(74); power with little pollution(75), but erosion and sedimentation problems(76) as well as lake eutrophication(77); improved water supplies(78),contaminated water supplies(79); better health(80), increase of parasitic diseases(81); improved agriculture(82), loss of fertile land(83); flood control(84), catastrophic flooding(85) and earthquakes(86); preservation and introduction of new animal and plant species(87), some of them damaging to the environment (88), local extinction of animals and plants(89); new jobs(90), loss of livelihood(91); prestige for the government(92), and financial loss for the government(93).

There are good and bad aspects about water resources development for power, but, with a little care and less emphasis on maximising power production, many of the problems could be avoided. Many of the above aspects are apparent in Brazil, but little documentation exists.

The standard of living of the middle class urban dwellers in Brazil is high. The city centres are well supplied with electrical power and many of the trappings of the developed world, including electrically operated transport systems(94). Most of Brazil's reservoirs for power have not required the resettlement of great numbers of people. UHE Sobradinho, where 70 000 people were moved, is an exception(95), but there is currently unrest over the proposed rio Uruguaī basin developments(96)(see p.108) and controversy over the Amerindians to be resettled as a result of the impoundment of lake Tucuruī(97)(see p.287).

At UHE Furnas, measures are being taken to prevent erosion by the planting of grasses and trees(98). Many of Brazil's rivers carry a heavy silt load, and, presumably, some reservoirs must be filling up with sediment, but this is not a phenomenon on which there is much published material. The improvement of water supplies in Brazil, as a result of water resources development for power, tends to be incidental rather than intended. In some instances, there is improved water supply, as a result of construction of water treatment plants for the towns developed as part of the power station infrastructure, such as at UHE Itaipu(99) and UHE Tucuruí(100). But, for those not resident in the townships, burgeoning slums in the villages outside and the use of available water by increased numbers of people, coupled with poor sanitation, leads to contaminated water supplies.

At most of the hydroelectric power station sites health programmes have been in operation, even during the 1920s (see p.89), and at UHE Itaipu and UHE Tucuruí well equipped hospitals and health centres have been built(101,102). The workers coming to the sites, and their families, are given a health screening. However, those moving into the villages outside remain unscreened. All the common waterborne diseases are prevalent in Brazil : malaria; schistosomiasis; filariasis; yellow fever; onchocerciasis, a disease of African origin has spread to Surinam and is now reported to be on the increase in the state of Pará, Brazil(103); the enteric diseases transmitted by poor hygiene - dysentery, gastroenteritis and diarrhoea; and hepatitis.

Two diseases which pose a threat to the poorer Brazilian communities, especially under the boom town conditions which exist in the villages close to the construction sites, are bubonic plague and Chagas' disease. The former is transmitted by the bite of an infected rat flea(104), and the latter - American trypanosomiasis, is transmitted by a reduviid bug which lives in the walls of mud and thatch dwellings(105).

There are no recorded instances of induced seismicity as a result of the construction of Brazilian dams, although fears have been expressed about UHE Itaipu((106). Catastrophic flooding has occurred, however, on a number of occasions in Brazil, as a result of water resources development. Two dams were overtopped and breached in 1977, as a result of the non-opening of the floodgates, and this caused considerable damage downstream. The two dams, Euclides da Cunha and Armando de Salles Oliveira, are being rebuilt(107). The dam at Sobradinho was intended to alleviate flooding in the rio São Francisco valley, but the 1980 floods, experienced after the completion of the dam, were the worst ever recorded(108).

At the behest of the World Bank, Brazil now undertakes environmental impact reconnaissance surveys for all its major water power development projects. All of the surveys so far executed, have recommended that certain measures be taken to protect the environment and the people, and that investigations should be made of the multiple uses which could be made of the reservoirs(109-111). Both the available literature and observations made on site visits give the impression that such surveys are ignored.

Multiple use of reservoirs in Brazil is not common. Of 23 reservoirs with a storage volume greater than $10^6 m^3$ of water, all were used for power production, 11 for flood control, 8 for supply of water to industry or urban populations, four for effluent disposal, three for commercial navigation, 15 for commercial fishing, seven for intensive fish culture, seven for vazante agriculture and seven for irrigation(112). The best established fishery is at UHE Furnas, where several species of commercial fish are bred at the fish station and then released into the reservoir(113).

Environmental issues are increasingly becoming more important in Brazil, and the Departamento do Meio Ambiente, within the Diretoria de Coordenação of ELETROBRÁS undertakes studies of some of the environmental ramifications of power production(114). However, despite such studies, the final decisions in Brazil are almost always based on the economic and political factors involved in electrical power production. To date, none of Brazil's hydroelectric schemes have been serious financial disasters, but the escalating costs and increasing debts for UHE Itaipu and UHE Tucuruí could change this situation. It is likely, however, that they will probably be overshadowed by the financial burden caused by the nuclear power stations which are also currently under construction.

Geography of Brazil

Brazil is the fifth largest country in the world. It has a total area of 8.5×10^6 km^2, almost as large as that of the USA. It shares 15 719 km of frontier with ten of the twelve South American republics (save Chile and Ecuador). Its coastline is 7 408 km long. The estimated population in 1978 was 113×10^6 with an estimated growth rate of 2.9% in 1977(115). By the year 2000 AD this is expected to have risen to approximately 210×10^6 with a slight slowing down of the growth rate to 2.75% between 1980 and 1990 and to 2.58% from 1990 to the year 2000(116). The average demographic density is 13 inhabitants km^{-2}, but this masks significant inter-regional differences(117). In the Amazon region much of the land is uninhabited, with an average population density of 1.5 inhabitants km^{-2}. In the central states of Goiás and Mato Grosso this rises to 2.7, and in the highly populous South-East it rises to 203 inhabitants km^{-2} in the state of Rio de Janeiro(117).

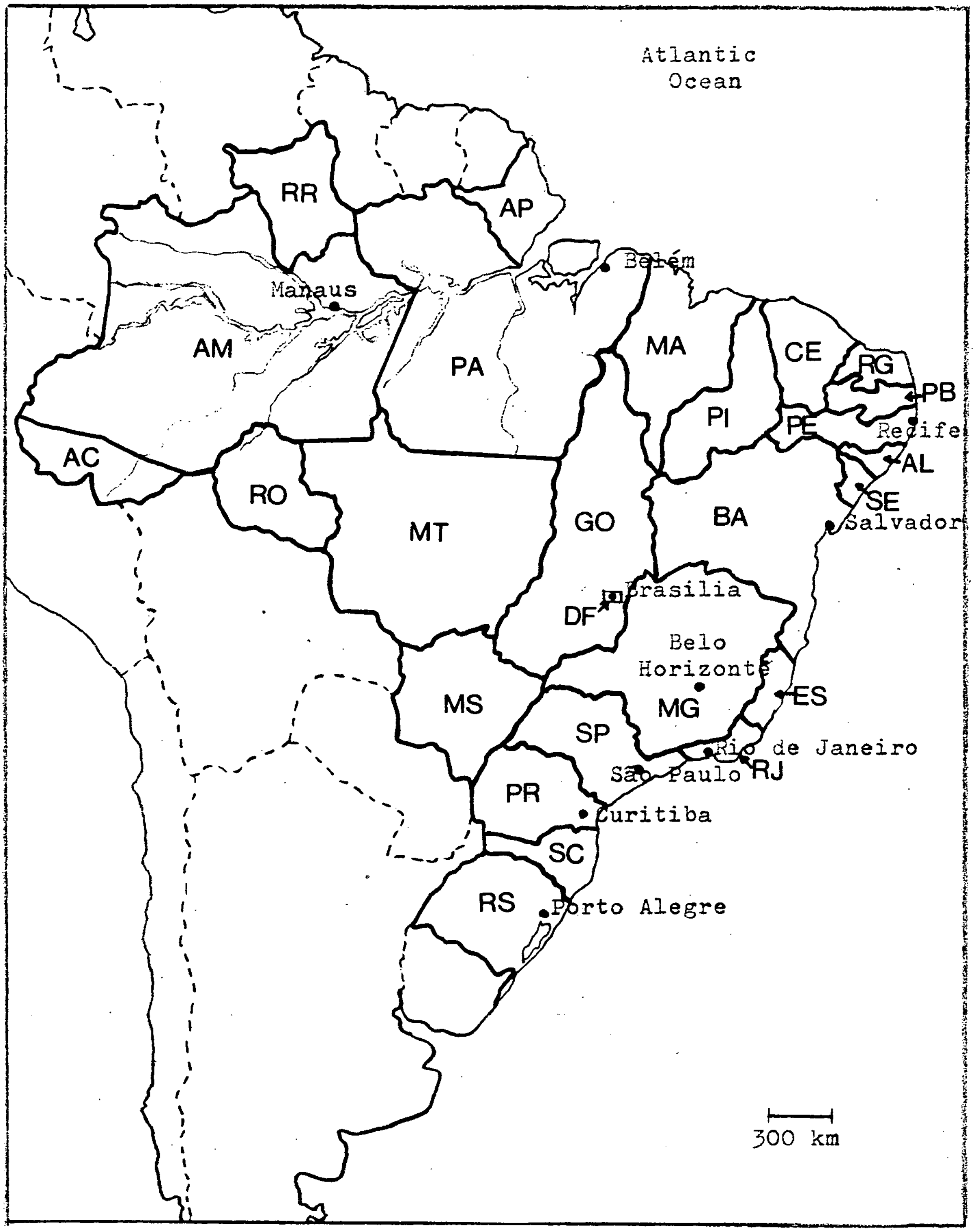
Brazil is a Federative Republic, comprising 22 states, one Federal District (the capital Brasília) and four Federal territories, see figure 1.1. Each state and territory is self governing, with overall control being exercised by the Federal Government.

Five eighths of Brazil is covered by plateaux, the remainder is plain. The Brazilian Highlands have an average altitude of 500 m, and the highest mountain, Pico da Neblina in the Guiana Highlands, rises to 3 014 m. The highest edge of the Brazilian Highlands, known as the Great Escarpment or Serra do Mar, descends steeply into the Atlantic Ocean, forming an almost impenetrable barrier from the sea coast for almost 3 200 km, from Salvador, in the state of Bahia, to Rio Grande do Sul. This difficulty of access to the interior of Brazil has often been cited as the reason for its delayed development(119). The northern half of the country is dominated by the immense forests of the great Amazon river basin.

Climate

The climate in Brazil varies widely. Most of this large country lies in the tropics, with the equator passing through the city of Macapá, in the territory of Amapá, in the north, and the Tropic of Capricorn crossing Brazil just north of São Paulo city. The Amazon region experiences an annual average temperature of between 22 °C and 26 °C, with small seasonal variation between the warmest and coldest months. The area is generally damp, with the average humidity in

Figure 1.1 : States and Principal Towns of Brazil



AC	Acre	MA	Maranhão	RJ	Rio de Janeiro
AL	Alagoas	MT	Mato Grosso	RG	Rio Grande do Norte
AP	Amapá	MS	Mato Grosso do Sul	RS	Rio Grande do Sul
AM	Amazonas	MG	Minas Gerais	RO	Rondônia
BA	Bahia	PA	Pará	RR	Roraima
CE	Ceará	PB	Paraíba	SC	Santa Catarina
DF	Distrito Federal	PR	Paraná	SP	São Paulo
ES	Espirito Santo	PE	Pernambuco	SE	Sergipe
GO	Goiás	PI	Piauí		

Source : Guia Rodoviaria do Brasil, April 1980

Manaus between 80% and 90% and an average regional rainfall greater than 2 000 mm. The North-East shows a greater seasonal variation. In some areas temperatures greater than 37 °C are common, but, on average, the annual temperature does not exceed 28 °C. Unlike most of Brazil, which has a moderate rainfall of 1 000 to 1 500 mm per year, much of the North-East is subject to prolonged droughts, and the average annual rainfall is often less than 600 mm. As a result, this agriculturally dominated region is poverty stricken.

On the Atlantic coast from Recife to Rio de Janeiro the mean temperatures range from 23 °C to 27 °C but in the interior, on the higher plateaux they are lower, ranging from 18 °C to 21 °C. The rainfall on the coast is high in places and the area is humid, due to the effect of the Serra do Mar on the Trade Winds. In the interior there is a distinct dry season. The south of the country experiences a more temperate climate. The average temperature ranges from 17 °C to 19 °C, and frosts, even snow, occur regularly during the winter.

Vegetation

The climate has a profound effect on the range of vegetation. There are several distinct types; the most extensive being the primaeval tropical rain forest covering $5x10^6$ km^2 of the Amazon basin, both in northern Brazil and neighbouring countries. The arid North-East, despite quite fertile soil, is covered by "coatinga" or scrubby woodland, and is difficult to farm successfully, due to the commonly occurring droughts. Until this century, the most fertile region was a narrow belt of semi-deciduous forest which stretched from Natal, in Rio Grande do Norte, to Porto Alegre, in Rio Grande do Sul, widening in southern Minas Gerais and São Paulo States.

However, lack of soil conservation has reduced its value considerably. South of the Amazon forest and west of the semi-deciduous forest, most of the interior is covered by woodland savannah known as "campo cerrado". It is unsuitable for crop growing without the use of fertilizers. The "pantanal", a mixture of wet savannah and palm trees, is located in the flood plain of the Alto Rio Paraguaī, and, in the dry season, it is used for cattle grazing. The temperate zone in the South is, in terms of vegetation, quite distinct from the rest of Brazil. In the far south are the grasslands used for cattle raising and wheat growing, and, north of the rio Uruguaī, it is thickly forested with semi-deciduous pine trees and broadleaf deciduous trees. Much of it has been reforested with eucalyptus and softwoods.

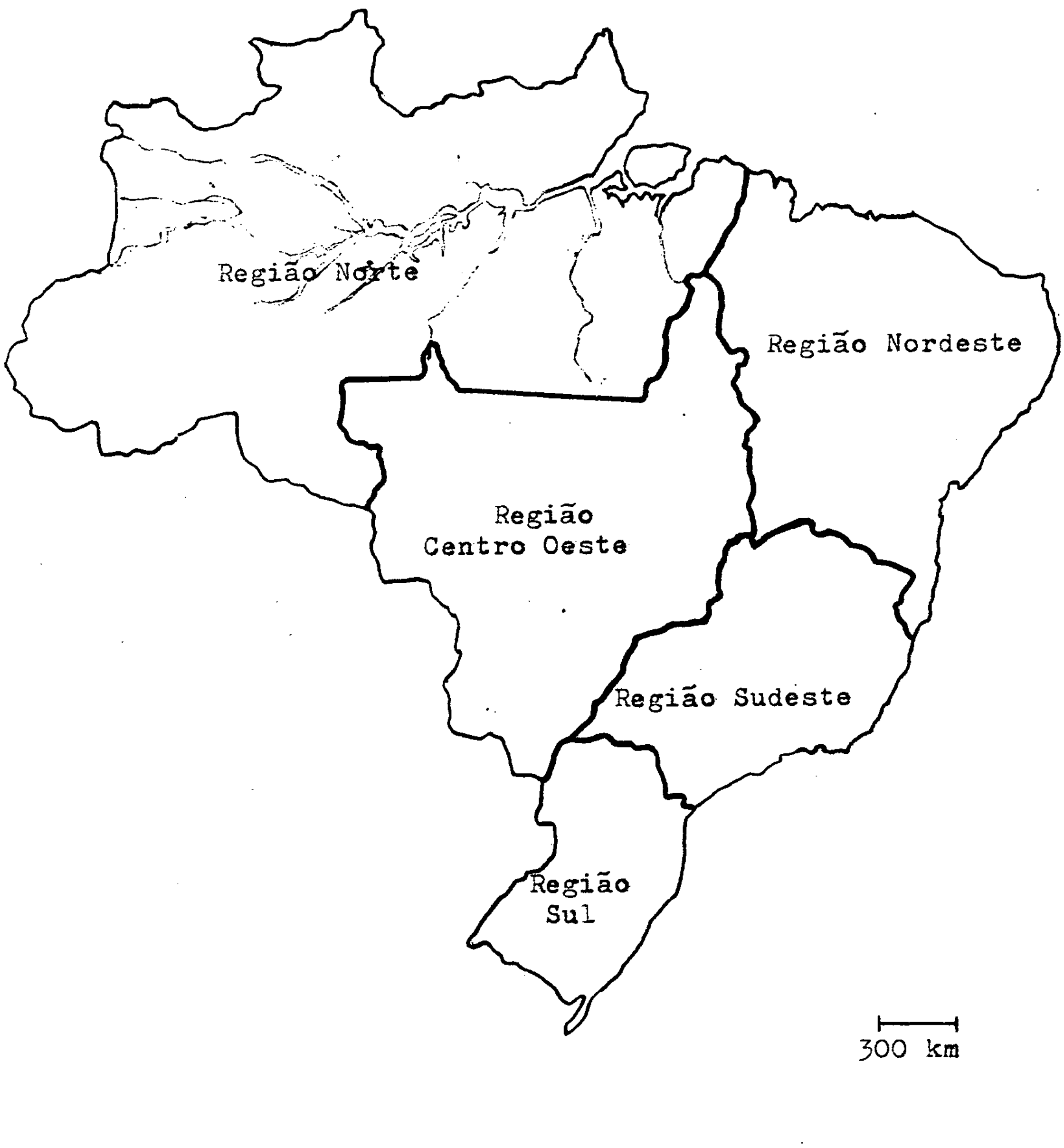
Regions

The country can be divided naturally into five large regions (see figure 1.2). The North is the largest and least inhabited, and includes the states of Parã, Amazonas and Acre, and the territories of Amapã, Roraīma and Rondōnia. The North-East is the poorest region in Brazil, with extremely low income levels. It comprises the states of Maranhão, Piauī, Cearã, Rio Grande do Norte, Paraiba, Pernambuco, Alagoas, Sergipe and Bahia.

The richest and most densely populated region is the South East, (sometimes referred to as South Central). It is the industrial and economic heart of the country, and comprises the states of Rio de Janeiro*, Espirito Santo, São Paulo and Minas Gerais. The South is

*The present state of Rio de Janeiro replaces the old federal district of the same name and the state of Guanabara.

Figure 1.2 : Regional Divisions in Brazil



Source : Guia Rodoviaria do Brasil, April 1980.

very European and includes the states of Paraná, Santa Catarina and Rio Grande do Sul. The sparsely populated, and often "forgotten" Centre West region consists of the states of Goías, Mato Grosso, Mato Grosso do Sul and the new Federal District (Distrito Federal) of Brasília.

Principal Cities

The centre of the Brazilian Federal Government is in the new capital, Brasília. This specially designed city was inaugurated, in 1960, as a showpiece of modern Brazilian architecture and town planning. It is situated almost in the geometric centre of the country, and it was intended to open the way for the development of the interior. Its population has reached almost one million inhabitants. Rio de Janeiro was the old Federal Capital for 200 years. Many describe it as the most beautiful city in the world. It is a great industrial, cultural and tourist centre, with a population of approximately five million.

The largest city in Brazil is the sprawling conurbation of São Paulo. It is the major industrial and commercial centre, with a population variously estimated as between seven and ten million. If there is no decrease in its growth rate of 350 000 per year it will be the largest city in the world by the end of this century. Belo Horizonte, a new, characterless city, the capital of Minas Gerais, is growing fast as an industrial centre and forms the third apex of the industrial triangle formed with the cities of São Paulo and Rio de Janeiro. Recife is the most important industrial city in the North and Salvador, a cultural and tourist centre, was the very first Brazilian capital. Manaus, in the heart of the Amazon basin, was an important city during the rubber boom of the nineteenth century, but, after a long decline, it is currently being bolstered by the Brazilian economy and has been created a "zona franca" (free trade zone)(120).

History of Brazil

Brazil was discovered by the Portuguese navigator Pedro Alvares Cabral in 1500 A.D.. The original inhabitants were Tupi-Guaranī Indians, and the first European settlement was in Salvador, Bahia. In 1494, before the discovery of Brazil, Pope Alexander VI, in an attempt to forestall territorial disputes between Spain and Portugal, had drawn up the Treaty of Tordesillas. This established an imaginary line, the Tordesillas Line, running from the North Pole to the South Pole 370 leagues west of the Cape Verde Islands. Lands to the east of this line were to belong to Portugal, and those to the west to Spain. This should have put most of Brazil under Spanish control, however, with no frontiers in their way the Portuguese explorers pushed into the hinterland, and when, after a period of 60 years under the Spanish Crown, they recovered their autonomy in 1640, they refused to relinquish the lands they had occupied west of the Tordesillas Line. The frontiers of Brazil which were recognised during its time as a Portuguese colony were retained after its independence in 1822.

The varied racial mix to be found in Brazil is as a result of the settlement patterns which have emerged over the years. The first settlers were wealthy Portuguese who established large sugar plantations, in the North East, and imported slaves from West Africa and Angola to work them. As a result, the dominant racial type in that region is a mixture of European and negro. The South and South

East received large numbers of immigrants from Europe, principally of Portuguese, German, Italian and Slav descent, as well as some Arabs. In fact, immigration only effectively began after 1850 and different groups settled in different regions.

The Germans and some of the Italians went to the South, as small scale agriculturalists, whereas the Portuguese and other Italians concentrated in the South East as industrialists. In addition, a large influx of Japanese into Brazil between the two World Wars gives São Paulo city the largest population of Japanese in any city outside Tokyo. They have retained their racial identity, and have been very successful as farmers and market gardeners. In the Amazon region the racial mix is between Amerindian and European, but only within the cities has there been any intermarrying(121).

Brazil tries hard to portray the picture of being a homogeneous society, where there is no social or employment prejudice, despite the complex variety of ethnic types. In many ways this is the case, but it is an undeniable fact that the rich and powerful are white, or predominantly so, the poor tend to be black, and the Amerindians are definitely third class citizens. As time passes, the situation is becoming more explosive(122).

The first system of government adopted by the settlers was a form of feudal principality, which was then replaced by a viceroy in 1572. In the same year the colony experimentally divided into two; in the main, settlers from the north of Portugal went to the north of Brazil, capital Salvador, and those from south Portugal to south Brazil, capital Rio de Janeiro. Rio de Janeiro was made the sole capital in 1763. A colonial constitution remained in force for three hundred years, and it was not until towards the end of the eighteenth century that nationalism arose, and the settlers began to resent paying revenue to the Portuguese Crown. However, independence resulted mainly from the enforced exile of the Portuguese Royal Family in Brazil in 1808. In 1815 the United Kingdom of Brazil and Portugal was established, and in 1822, Prince Pedro, heir to the Portuguese throne, gave in to the pressures from the ruling sectors of the colonial society and declared Brazil an independent Empire.

He abdicated in 1831 in favour of his five year old son, Dom Pedro II, who was placed in the charge of a regent.Dom Pedro II ruled for nearly 50 years after assuming power in 1840. He was a good ruler who encouraged agriculture, promoted education, increased communications and stamped out corruption. He also encouraged the use of electricity (see p.72). He abolished slavery in May 1888, and it was this act which lost him his crown. He was banished to Europe in November 1889, and Brazil became a Federal Republic, divided into states.

The period of the First Republic lasted until 1930. It was a comparatively eventless time of expansion and reasonable prosperity. Presidents were elected and succeeded each other in office. In 1930 the Government was overthrown, by force, by a revolutionary movement led by Getulio Vargas, Governor of Rio Grande do Sul, who assumed executive power as dictator. He introduced a new constitution in 1934 and gave the vote to women. As a result of the social measures he introduced he became known as the "Father of the Poor", but was forced to resign in October 1945. He was succeeded by Eurico G. Dutra as elected president. However, Vargas was elected back into office as President in 1950, only to commit suicide in 1954 during investigations of corruption within his administration. Jucelino Kubitschek came to power in 1955, and his main claim to fame was probably the moving of the Federal Capital to Brasilia.

The early 1960s were years of political unrest, with the resignation of President Jânio Quadros after seven months, and, in 1964, a military takeover of the Government deposed President João Goulart and put General H.A. Castello Branco into power. Brazil has been under military rule ever since, although moves are being made to return to a civilian government. This is planned for 1985(123) but there are doubts that the current Government, under President João Batista Figueiredo and his supporters, will then hand over the power(124).

The political climate is changing from the somnalent euphoria of the "economic miracle" years of the later 1960s. The world energy crisis, followed by the world economic recession, has hit Brazil hard. The widening gap between the rich and the poor has brought about social unrest with strikes in key industries(125). The fear that civilian power will not return is encouraging the emergence of political activists. For the period of study covered in this thesis, Brazil has remained in a relatively stable situation, except for the early 1960s, but there is no guarantee that this changing mood will not, in the future, affect proposed plans and developments.

Resources

i. Minerals

Brazil possesses substantial deposits of minerals, some of which have already been exploited, starting with the gold and diamond rush of the eighteenth century in the state of Minas Gerais. This state is still the centre of the mining industry, where it is the main Brazilian producer of iron ore, bauxite, niobium, beryllium, zirconium, quartz crystals, graphite, mica, marble and talc. Copper, lead and tungsten are mined in other states. The existence of extensive mineral deposits in the Amazon Basin is suspected, but, as yet, there has been no large scale attempt to exploit them.

Brazil's major mineral assets include some of the largest reserves of high quality iron ore - located in the "Iron Quadrangle" of Minas Gerais, and in the Carajās mountains in the Amazon basin. Mining of the latter has only recently begun(126), but, in 1974, 75 190 metric tons of ore were mined in Minas Gerais, of which 59 429 metric tons were exported(127). Reserves of bauxite are extensive. The Trombetas and Paragominas reserves in the Amazon basin are extremely large (over 10^9 tons), and the utilisation of these reserves was the original reasoning behind the construction of UHE Tucuruī (see chapter 6). Despite considerable bauxite reserves in Minas Gerais as well as the Amazon region, Brazil still has to import aluminium metal, as its own production is insufficient to meet internal demand.

Niobium is a major Brazilian export. The largest reserves in the world of pyrochlore (the ore) are found in Brazil, which supplies 60% of the Western World's total consumption of the ore. There are a number of large reserves of nickel and titanium ores which, as yet, cannot be exploited as they are in a form where commercial extraction is not yet possible. The reserves of copper ore are very small and inadequate to meet the country's demands. However, the two principal mineral deficiencies, from which Brazil suffers, are very small reserves of poor quality coal and an almost complete lack of oil. The major coal reserves are to be found in Santa Catarina, and a major development programme is in progress to increase production for use in the steel industry. However, the ash content of the coal must be reduced before it can be used(128).

It is difficult to obtain accurate information on Brazilian oil reserves, estimates are often coloured with optimism. Evidence of oil is periodically located, but there have been no announcements of major finds. Much of the search is operated by means of risk contracts awarded to foreign companies exploring the continental shelf off the north east coast of Brazil(129). The situation precipitated by the world oil crisis in 1973, sharply affected the balance of payments of this oil importing country(130) and is responsible for the adoption of Brazil's ambitious alcohol programme, where sugar cane and cassava are processed to produce alcohol of a grade suitable for use in cars (see p.30)(131,132).

ii. Agriculture

Agriculture forms a vital part of the Brazilian economy. In 1977 it accounted for 14% of the gross domestic product, 60% of exports, and 44% of the country's workforce. Despite some modernization it is still a low productivity industry. However, 95% of the domestic food needs were met by internal production, with the exception of wheat. The principal export crop is coffee, closely followed by soya beans, and then sugar, cocoa, maize, tobacco, cotton and fruits(133,134).

iii. Industry

The industrial sector has been the most dynamic sector of the

Brazilian economy since the end of the Second World War. This has been due partly to government policies, but also to external influences. Until 1930, industrial growth was slow, and Brazil depended on its coffee exports for foreign exchange earnings. The Wall Street Crash in New York, in 1929, meant the collapse of the coffee market with the result that the government encouraged investment in manufacturing instead. By 1939 a growth rate of 5% per year had been achieved.

The Second World War was accompanied by a restriction of the international markets for the traditional agricultural goods, and made importation of other goods difficult. This boosted the industrial growth rate to 5.5% per year. After the war Brazil adopted a policy of importation of industrial equipment, and essential raw materials, and introduced selective import controls on consumer goods. From then, until 1961, the average industrial growth rate was 9.7% per year. Inflation in the early 1960s caused stagnation of industry and in the rest of the Brazilian economy. Until that time, the economic policies pursued had relied on the belief that stimulation of industrial growth would create the necessary conditions for national development.

After the 1964 revolution new economic policies were adopted. Foreign investment was attracted back into Brazil with a reduction of the rate of inflation and a reformation of the fiscal and monetary systems. The manufactured goods and consumer durables industries expanded. But the oil crisis, and the accompanying increase in oil prices in 1973, led to a reappraisal of Brazilian industrial policy, and a reduction in the importation of oil, in order to improve the balance of payments. According to the Second National Development

Plan, development will be concentrated in certain basic industrial sectors, including capital goods, petrochemicals, electronics and the steel industry(135).

It is noticable that this policy of import substitution is having a dramatic effect in the electrical power industry. Whereas, in the 1960s the heavy generating equipment and other machinery imported for the UHE Furnas project was 95% imported(136), 90% of it is produced in Brazil for the UHE Itaipu project(137). The net result of this industrial expansion has been a rapid increase in the need for electrical energy, and much of the Brazilian energy programme is aimed at meeting these needs.

The main industries in Brazil are centred in the industrialised state of São Paulo, and include motor cars, shipbuilding, metals (principally steel), foodstuffs,textiles and chemicals(138).

CHAPTER 2

Electrical Energy in Brazil

Energy Profile of Brazil

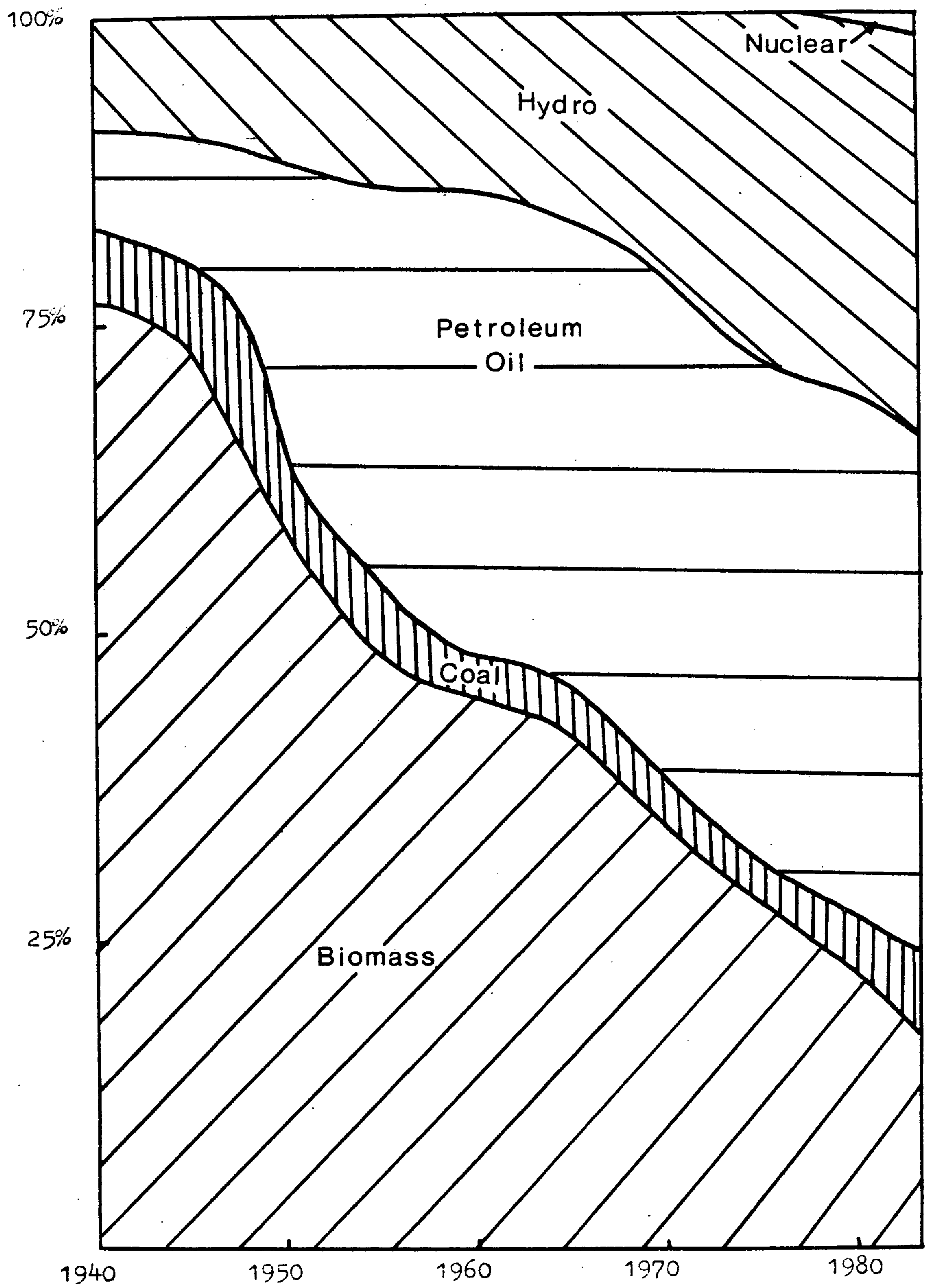
"It will not be possible to grow rapidly without a rapid expansion in the supply of energy...In the long run Brazil must have its own basic sources of energy. A strategy aimed at this objective will take at least a decade and will depend essentially on the results of prospecting for petroleum, exploitation of shale, discovery of important deposits of uranium and on the best solution which world technology finds for the principal new form of energy as a substitute for oil"(139).

This statement from the Brazilian Government's Second National Development plan shows the emphasis which Brazil puts upon energy as a development tool, and the line of thought being taken as to possible energy sources. It neglects the country's primary source of electrical energy, hydroelectricity, as it is "taken for granted" that this source will be developed to the full.

When Brazil entered its accelerated phase of post-Second World War industrialization there was an exodus of rural peoples to urban centres, and an increase of the per capita energy consumption(140). According to Goldemberg, the energy consumption as a function of per capita income increased in a similar manner to the increase observed in the developed countries, and Brazil adopted the energy-intensive consumption patterns of the great industrial countries(141).

From figure 2.1 it can be seen that the relative importance of

Figure 2.1 : Energy Consumption in Brazil, 1940-1980.



Source : Goldemburg J. "Brazil : Energy Options and Current Outlook", Science, Vol.200, 14 April 1978, p.160.

biomass decreased dramatically, whilst the consumption of oil, which at the time was still cheap and abundant, rose considerably. Coal maintained its traditionally insignificant role, but the share of hydroelectric power increased to 20% of total energy consumption(142).

As a result there is an increase in the importation of petroleum oil, and from figure 2.2 the estimates indicate that consumption of petroleum oil and similar products will continue to rise, although Brazil has to import most of that which it consumes. The contribution of biomass remains almost constant, showing just a slight increase, but although consumption of hydroelectric power and nuclear power are expected to rise sharply, so is the consumption of petroleum and other liquid fuels.

<u>Table II.i : Non-renewable Energy Resources in Brazil</u>

Resource	Reserves 1972 $x10^6$ tons	Total Energy Content $x10^{15}$ J	% of Total
Crude oil	106.5	4 687	11.1
Natural gas*	35.8	1 468	3.3
Shale oil	497.0	21 868	52.0
Coal	688.0	13 760	32.7
Uranium †	0.0032	309	0.7

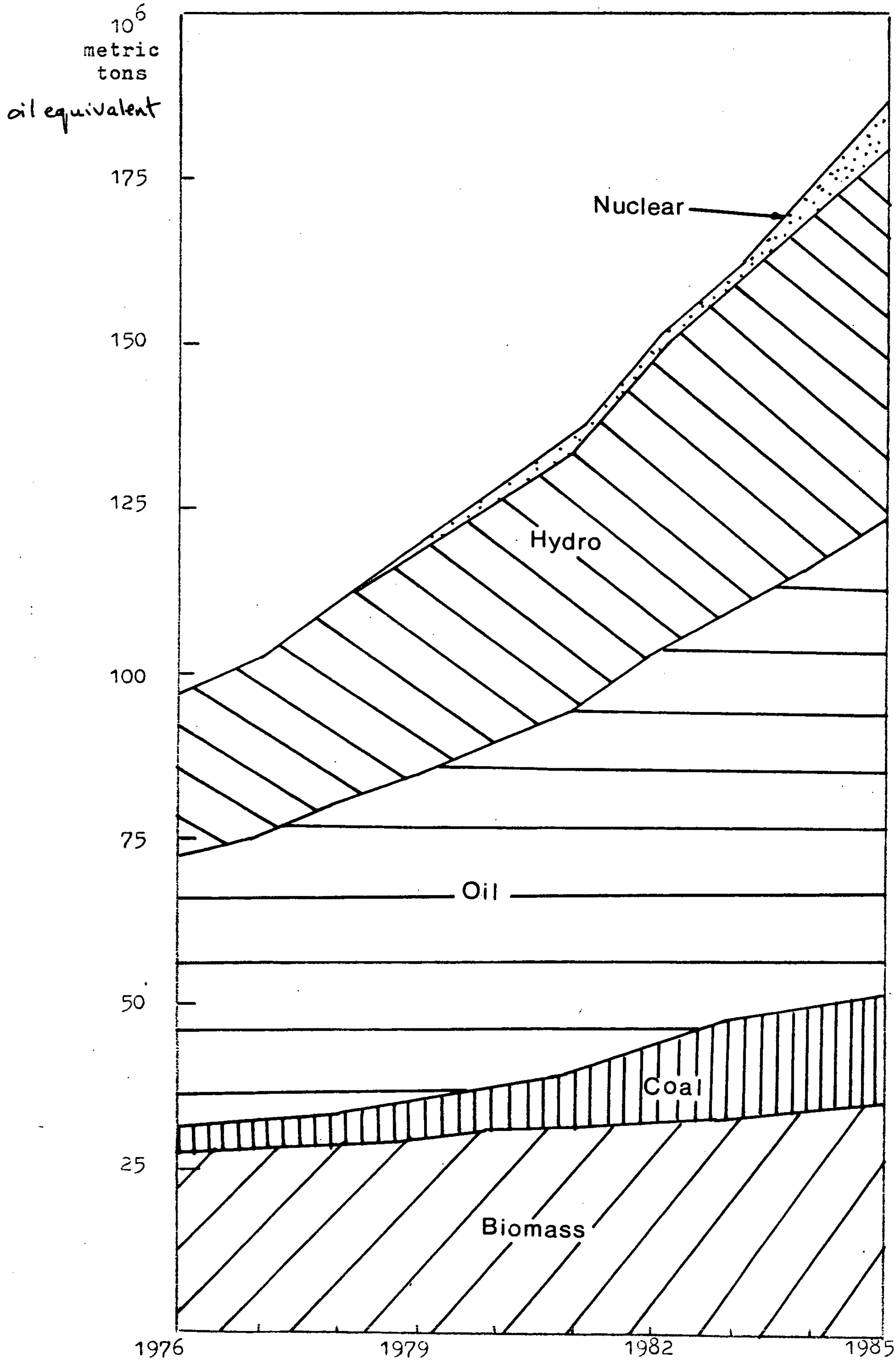
Source : Goldemberg (J.), Science, 200 (April), 1978, 162.

* km^3

† without plutonium recycling

From tableII.i, which shows the proven reserves of Brazil's non-renewable energy resources, it may be seen how disappointing the oil reserves are. Despite there being over $3x10^6$ km^2 of onshore sedimentary basins and 800 000 km^2 of offshore continental shelf in Brazil, the results of oil exploration have not been encouraging.

Figure 2.2 : Primary Energy Consumption Estimates, 1976-1985



Source : "Brazil's Energy and Heavy Industries", Brazilian Embassy publication no.15, p.9.

Since 1939, more than 3 900 wells have been drilled, but the recoverable reserves are only 106×10^6 tonnes, and annual production covers less than internal needs. The rest has to be imported(143).

The Second National Development Plan projected a massive prospecting programme on the continental shelf and a production programme to raise the investment by the Government from 1975-1979 in this area by 225% over that in the period 1970-1974. It was expected that total investments in oil would be at least Cr\$ 56×10^9 (1979 prices)(144). Much of the prospecting being undertaken is by means of risk contracts awarded to foreign companies(145).

In addition to trying to increase internal production of petroleum oil, Brazil has embarked upon a programme of electrification of the railways(146), and, in 1975, the Programa Nacional do Alcohol (PNA) was launched. Brazil's first experiments, in the 1920s, with gasohol, a mixture of petrol and alcohol, were so successful that in the next decade it became mandatory for alcohol to be added to petrol. This was not an energy conservation measure, but a means of ensuring the market for sugarcane products. However, the PNA is a conservation measure, and originally it was intended to establish the addition of up to 20% of alcohol to petrol as a national goal.

With the implied expanded market for ethanol, there has been considerable research into alternative feedstocks for alcohol distilleries. Of the existing or approved projects, as of July 1978, there were 208, sugarcane was the primary raw material, but also approved were cassava, sweet sorghum and babassu (a native Amazonian palm)(147). In fact, the first commercial plant in the world for the production of fuel alcohol from cassava was started up by PETROBRAS (the Brazilian Petroleum Corporation) in December 1977(148). Despite high investments and even higher initial costs, alcohol fuels would appear to have good prospects, and be able to recover capital in terms of the savings made on petroleum imports(149). Although the PNA programme has to overcome a number of problems, "it holds much promise for providing substantial energy and technological independence for South America's largest country"(150).

In 1977, petroleum accounted for 43% of Brazil's primary consumption, in a period of only a decade (1966-1976) it displaced biomass as the major primary energy source(151). However, Brazil is now urgently implementing petroleum substitution programmes as a result of the sudden escalation of the price of petroleum oil in 1973. In 1977, foreign petroleum alone consumed approximately 40% of Brazil's export revenues; with a resulting problem in the balance of payments, increased rate of inflation and a slow down in the GNP growth rate. Although the crisis occurred in 1973, the price of petroleum continues to rise, putting a severe financial strain on oil importing countries, especially those in the "Third World"(152). Inflation in Brazil has risen at an alarming rate, exceeding 100% in 1980(153). Much of this rapid inflation has been blamed on the rising price of oil(154).

By 1979, Brazil's external dependence on petroleum oil for the transport system and for industry (including the petrochemical industry) had surpassed 80%, and it was suggested that if 1% of the national territory be dedicated to the cultivation of sugarcane, cassava and other crops for alcohol production, the energy produced would be greater than three power stations the size of UHE

Itaipu(155), however, the environmental problems, in terms of land use and food production would be immense. In 1979, not only was alcohol mixed with petrol, but there were cars running solely on alcohol,and a number of Government agencies were maintaining fleets of such cars(156).

In December 1976, the Federal Government created the Projeto Ipiranga in order to study alternative sources of non-conventional energy, such as micro-hydrostations, alcohol power stations, and the use of wave and wind power, solar energy and animal wastes. Most of these power sources, if established, would be for isolated systems in the North and North East regions(157). Other than fuel for transport, and use of wood for cooking in some areas, most of Brazil's energy consumption is in the form of electricity.

Coal

Less than half the coal consumed in Brazil is used to generate electricity. Brazilian coal is of poor quality, with a high ash and sulphur content. The coal mined in the state of Santa Catarina is of better quality, and can be used for the production of metallurgical grade coking coal, whereas that from the states of Rio Grande do Sul and Paranã is only suitable for power stations.

Brazilian coal is expensive due to the mining difficulties, the requirement for treatment before use, and expensive transport costs as a result of poor transport facilities. Therefore, coal-fired power stations are uncommon, and tend to exist close to the mines or near to the ports where coal is imported. (Ironically, imported coal is cheaper than that produced locally)(158). At the beginning of 1974, there were only seven coal-fired power stations in operation in

Brazil, with a total installed capacity of 518 MW. Of these it was planned to retire three from operation that year (total capacity 62 MW), but a further two were under construction with installed capacities of 250 MW and 300 MW respectively. All of these coal-fired power stations are in the South region. It has, however, been decided that reserves in the region of Candiota, Rio Grande do Sul are such that it would be economical to construct a 1 200 MW coal-fired power station there, with a fuel cost competitive with that of nuclear fuel. The cost of use of coal in Santa Catarina was not considered competitive with nuclear fuel.

The high market projection for proposed generating installations for 1975-1985 suggested increasing the installed capacity of the two largest coal-fired stations, UTE Jorge Lacerda, in Santa Catarina, and UTE Candiota II, in Rio Grande do Sul to 482 MW and 432 MW respectively by 1980(159), but, according to the expansion programme in progress, UTE Jorge Lacerda is to have an installed capacity of 482 MW by mid-1980, and UHE Presidente Medici, in Rio Grande do Sul, is to undergo expansion, in 1983, to reach an installed capacity of 452 MW(160), instead of the previously proposed expansion of UTE Candiota.

Oil-fired power stations

The continuing increase in the price of petroleum oil has had a marked effect on the economic viability of Brazil's oil-fired power stations. In 1974, the cost of firm energy from such stations was 17.75 US$mill/kWh and has risen steadily. There are seven principal oil-fired power stations in operation, in the states of Rio de Janeiro, São Paulo and Rio Grande do Sul. A further 125 MW station is under construction in Minas Gerais. The total installed capacity is 1 155 MW, and a further 107 MW are operated by autoproducers. The two largest oil-fired stations are the old 'Light' stations of UTE Santa Cruz (560 MW) and UTE Piratinga (410 MW)(161) see p. 79. No new oil-fired stations are planned, and all the operation plans are trying to maximise the use of hydraulic energy.

Nuclear power

One of the most controversial aspects of Brazil's electric energy programme is the move towards nuclear power. It is a difficult subject upon which to acquire accurate information, even for those employed in the industry(162). ELETROBRAS is responsible for all electricity generation, but Empresas Nucleares Brasileiras S.A. (NUCLEBRAS) is the state holding company with responsibility for the Brazilian nuclear programme. At present, none of Brazil's electricity is nuclear generated, and there are only two nuclear power stations under construction, Angra dos Reis I and II.

Many countries suspect Brazil's motives for developing a nuclear power programme, especially as it refused to sign the treaty of non-proliferation of nuclear weapons in 1968(163). Brazil, however, states its intention is to ensure that it will be in a position to meet its future energy needs without depending on external sources of supply(164).

The Brazilian Government first announced its proposal to initiate a nuclear energy programme in 1965. The first station was proposed to have a potential of 500 MW and to be installed in the South East region. It was to start operation in the middle of the 1970s as a pioneering project to develop technical experience and expertise in the planning, construction and operation of nuclear power stations, as well as to speed up the introduction of the specialised technology needed by Brazilian industry(165).

The original plans, drawn up in the early 1970s, called for 60 nuclear power stations by the year 2 000, with an installed capacity of 75 GW. Its scale reflected the optimistic mood which prevailed at the peak of Brazil's "economic miracle". The number was soon reduced to a more realistic figure of eight(166). In 1972, the American company, Westinghouse Electric, was awarded the contract to build Brazil's first commercial nuclear power station at Angra dos Reis, 150 km south west of Rio de Janeiro. It is a pressurised water reactor (PWR) with a generating capacity of 626 MW. It was originally scheduled to start operation at the end of June 1976(167), but it has continually been beset with problems and surrounded by controversy. The reactor is the standard PWR type sold by Westinghouse, and its construction has required no contribution from national manufacturing capacity. The share of local suppliers in the project has only been 8%, and this comprised civil engineering works.

The site is reputed to be in Brazil's only known seismically active area, and there have been persistent problems with the foundations, due to the inadequate geological survey work originally done. The old Indian name for the beach on which construction is taking place, Itaorna, should have given a clue to the state of the bedrock, it means "rotting stone". By 1980, the start up was scheduled for 1981(168), in the third quarter(169), but to date there have been no newspaper reports that this has occurred.

It must be remembered that at the time of the world oil crisis in 1973, the technology for extremely long distance transmission of electricity was not well developed, thus the enormous reserves of hydraulic potential available in the Amazon Basin could not be considered as readily exploitable for supply to the industrial market of the South East region. As a result the almost universal cry from the electrical power industry was for nuclear power(170-172).

Technical studies carried out in 1973-1974 concluded that Brazil needed to have 10 GW of nuclear power on stream by 1990. Therefore, two further plants were scheduled to begin operation in 1982 and 1983 respectively, each with an installed capacity of 1.25 GW. It was decided that two light water/enriched uranium reactors should be built, using West German technology. In June 1975 an agreement was signed between Brazil and West Germany for the latter to supply the former with a total of eight nuclear reactors, an uranium enrichment plant, and a plant for the reprocessing of spent nuclear fuel(173). The German agreement thus encompasses all the aspects of nuclear technology, and the Brazilians are able to reach the capability of operating the complete nuclear fuel cycle. The uranium enrichment plant would break the North American monopoly, and the fuel recycling plant would enable the extraction of plutonium, which could be used for nuclear weapons(174).

However, at present, Brazil's main concern is the problem of constructing Angra II, on the same site as Angra I. Necessary reinforcements to the foundations have caused considerable delay, and the current schedule for start of operation of Angra II is mid-1986, and for the third station Angra III is mid-1987(175). These three power stations will be operated by Centrais Elétricas de Furnas (FURNAS), which has had to bear the excessive extra costs which have been incurred as a result of modifications and delays, mainly in the form of interest payments, totalling more than US$ 320×10^6 (1980 prices). As a result, when Angra I does come on stream, FURNAS will have to raise the price of its electricity to cover these costs.

The costs of the projects have tripled since the original estimates, and the financing loan of US$ 1.7×10^9 (1980 prices) is the largest ever obtained for a Brazilian project. As a result, there is a difficulty in persuading any of the electricity utilities to build the fourth nuclear power station. The Federal Government and NUCLEBRAS are pressurising CESP, but it prefers to build hydroelectric power stations at a quarter of the cost(176).

This difficulty has resulted in rumours that the Brazilian Government is going to renege on its agreement with West Germany. Certainly Brazil now sees no need for any extra nuclear power before 1995, other than from Angra's I,II and III(177), and the impression given is that it is quietly trying to forget that it has a nuclear programme. There is now serious opposition to nuclear power by the Brazilian public, and although Brazil reaffirmed, in 1977, that it had no intention of reviewing its 1975 agreement with West Germany(178), there is much pressure to do so(179). However, in an interview, in 1980, the then Minister of the Ministério das Minas e Energia (MME), César Cals, reiterated that the Brazilian nuclear programme is important, as it is predicted that after the year 2 000 Brazil will have to rely on nuclear power(180).

Hydraulic Resources

Brazil has an enormous potential for hydroelectric power generation, and increased use of this potential was one of Brazil's responses to the 1973 oil crisis. In fact, the World Bank has estimated that 60 developing countries plan to add 100 GW of hydrocapacity in the 1980s, although this is only a fraction of their estimated potential of 1 200 GW(181).

Estimates of the available hydraulic potential increase with time as improved methods of measurement and more precise information become available(182). In the 1940s, Brazil was ranked fourth in the world after the USSR, USA and Canada. Its estimated potential was then 15 GW. However, it was considered then, and it is still true, that estimates of water resources potential for power are unimportant without reference to the people who might use that power. In the 1940s, the potential available at the Iguaçu and Guiara falls in the state of Paraná was considered of little value, as the power could not be transmitted further than 400 km at that time, and there were no industrial towns within that radius to use the power. One engineer was quoted as saying :

> "Talk of the establishment of great industrial centres in the future in these remote and isolated places remains largely in the field of real estate promotion....The map of population is of more basic importance than the map of waterfalls in any attempt to interpret the potential power reserves of a country like Brazil"(183).

Until the 1960s, figures given for the hydroelectric potential in Brazil were essentially guesses, based upon very little verifiable information (due to the scarcity of accurate hydrological, geological and other data), and they were constrained within the maximum possible transmission distances.

It was only in the last twenty years, with the beginnings of a comprehensive electrical power industry in Brazil, that river basin hydroelectric potential inventories began to be made (see p.188). The

Table II.ii : Historic Evolution of Brazilian Hydraulic Potential

Year	Firm Energy MWav			Potential	Inventories
	Known	Estimated	Total	MW	
Up to 1955	-	-	7 500	15 000	None
1955	-	-	13 000	26 000	
1961	17 000	33 000	50 000	100 000	1st Amazon est.
1966	42 000	33 000	75 000	150 000	CANAMBRA inv.
1978	56 900	47 600	104 500	209 000	All Amazon est.

Source : Schulman (M.), Energia Elētrica, Ano 2 (20), 1979, 66.

first surveys were carried out by CANAMBRA, and, later, by ELETROBRAS and its subsidiaries. Of major importance to Brazil, in the 1960s, was the hydroelectric potential available in the industrial South East region and, as a result, CANAMBRA's first studies were in this region(184), followed by further studies in the South region(185). The CANAMBRA consortium was then contracted to extend its studies to the Northern region, under the co-ordination of the Comitê Coordenador de Estudos Energēticos da Amazonia (ENERAM), in order to survey the hydroelectric potentials near to the development poles in the region (see p.159). This was soon followed by an inventory of the potential of the basin of the rio São Francisco, co-ordinated by the Comitê Coordenador de Estudos Energēticos da Região Nordeste (ENERNORDE)(186). Finally, attention was turned to the whole Amazon basin, with studies being made by ELETRONORTE.

An inventory of the Amazon Basin has only recently become worthwhile, partly due to the possibility of long distance high voltage d.c. transmission, and partly due to the exhaustion of the hydroelectric potential in the industrial South East(187). Attention is also being refocussed on the rio Uruguaī basin, as the change in base conditions - the rise in oil prices, and the South East region power interconnection, have made development of this river more economically attractive than when first studied by CANAMBRA in the late 1960s(188).

Previously economic alternatives for power production in some areas are now extremely expensive, with rising fuel costs for the Amazonian oil-fired power stations making this form of energy prohibitively expensive.(189). In addition, a new philosophy has arisen in Brazil with respect to hydroelectric power development. The original surveys of river basins were purely to assess the potential for power but, more recently, there has been the evolution of the Brazilian awareness of the wider role of water than solely for the production of energy. This has led to the first efforts in the standardisation of the studies of water resources, through the development of integrated planning for the utilisation of the natural resources of the river basins. An example of this occurs in the rio São Francisco basin, where measures are being taken to regulate the river flow and to prevent the occurrence of serious floods(190).

This new and broader perspective on water resources planning can also have the effect of improving the economic viability of developments intended primarily for hydroelectric power production. This is particularly true in the basins of the rio Paraîba do Sul and the lower rio Doce, where the hydro-generation could be advantageously combined with urban water storage, effluent disposal, navigation and irrigation. The construction and operation costs would be shared between the various utilities involved, thus making some small hydroelectric schemes more economically attractive(191).

Brazil can be divided into eight principal hydrographic basins, as shown in figure 2.3. The divisions chosen are fairly arbitrary as there are a number of large rivers in the country, thus, the division of Brazil into principal basins depends mainly on topographical evidence, and also upon the economic and political importance of different regions. (Although separated out, the Uruguaĩ basin is a sub-basin of the Paranã basin, and the Tocantins-Araguaia basin is a sub-basin of the Amazon basin). The largest, and least exploited, basin is that of the river Amazon. The most exploited is the second largest, the Paranã basin, in whose headwaters are most of the São Paulo river development schemes.

Table II.iii : Hydraulic Potential in Brazil, by Region

River Basin	Area # $\times 10^3$ km^2	Estimated Potential GW 1971 *	1978 +
Amazon	3 985	5.6	74.2
N.E. Atlantic	885	0.4	1.4
S. Francisco	631	14.6	11.9
E. Atlantic	569	7.8	-
S.E. Atlantic	224	2.4	-
Uruguaĩ	178	2.0	48.8 (Uruguaĩ and Paranã together)
Paranã	1 237	45.7	
Tocantins-Araguaia	803	0.7	25.2
Total(est.+dev.)	-	79.3	209.0

Sources :

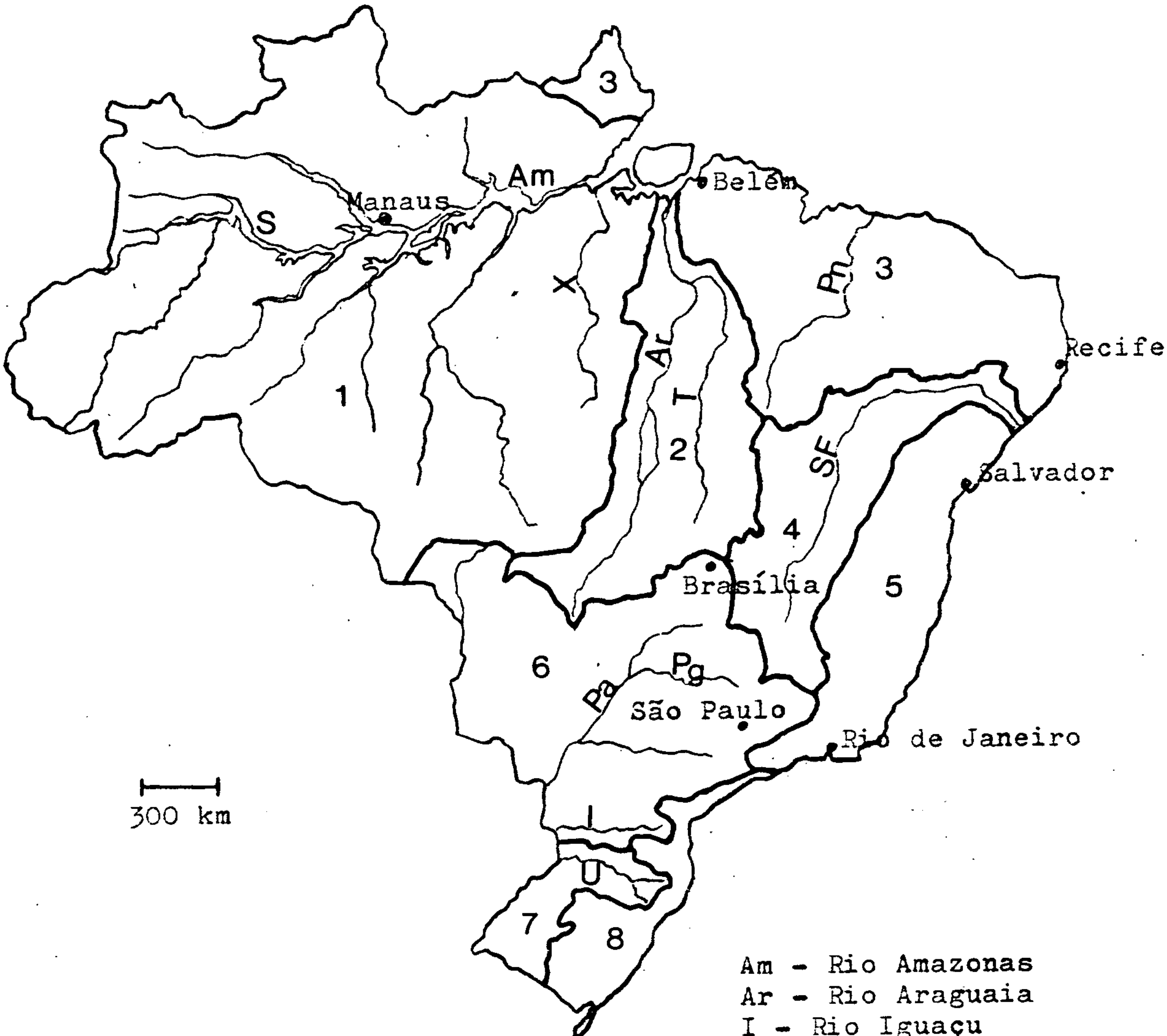
+ Llano B.G. Rev. do Clube de Engenharia, Ano 93 (417), 1978, 69

* Anon., Mundo Elētrico, Ano 12(139), 1971, 29.

ELETROBRAS public relations document "Brazil 209 milhões de kW"

From tables II.iii and II.iv, it is apparent that more than half of Brazil's hydroelectric potential is estimated, not firm. This is principally because 72.2% of the potential in the region of

Figure 2.3 : Principal Hydrographic Basins in Brazil



1 - Amazonas Basin
2 - Tocantins Basin
3 - Basins of the N/NE Atlantic
4 - Sao Francisco Basin
5 - Basins of the E Atlantic
6 - Parana Basin
7 - Uruguai Basin
8 - Basins of the SE Atlantic

Am - Rio Amazonas
Ar - Rio Araguaia
I - Rio Iguaçu
Pa - Rio Paraná
Pg - Rio Paraguai
Pn - Rio Parnaiba
S - Rio Solimões
SF - Rio São Francisco
T - Rio Tocantins
U - Rio Uruguai
X - Rio Xingu

Source : Mundo Eletrico, Ano 18, no.207A, December 1976, p.86.

Table II.iv : Hydraulic Potential, by Subsidiary

Region	Installed Potential						
	Dev. or constr.		Inv.		Est.		Total
	GW	%	GW	%	GW	%	
ELETRONORTE	4.1	4.4	21.1	23.4	70.8	72.2	96.0
CHESF	8.3	48.5	5.6	47.9	0.5	3.6	14.4
FURNAS	23.2	41.3	18.5	35.3	13.4	23.4	55.1
ELETROSUL	13.3	29.3	16.5	43.3	13.7	27.4	43.5
Total	48.9	22.0	61.7	32.4	98.4	45.6	209.0

Source : Schulman (M.), Energia Elētrica, Ano 2 (20), 1979, 68.

operation of ELETRONORTE has yet to be assessed. In the industrial South East, the region of operation of FURNAS, the high figure for the percentage of estimated potential, 23.4%, is a result of the non-inventoried areas in Mato Grosso do Sul, and of the re-appraisal of some regions previously rejected as economically non-viable.

The usually quoted figure for the hydroelectric potential in Brazil is 209 GW. Of this approximately 90 GW are to be found in Amazon basin(192,193) Although it is likely that a considerable amount of the available potential will eventually be used from the north flowing tributaries of the river Amazon, development of the south flowing tributaries is likely to be only in isolated areas, in order to satisfy individual markets.

The total figure for the estimated hydroelectric potential of 209 GW, puts Brazil in third place in the world, behind China and the USSR, in terms of available hydroelectric resources. For calculation of the firm energy Brazil uses a capacity factor of 50% for conventional power stations, which gives a value for the firm energy of 104.5 GW av.. This estimate does not take into account the possibilities of the inclusion of pumped storage or mini-hydroelectric schemes(194).

Pumped storage is now being considered in Brazil as it appears to be economically attractive. The topographical and geological conditions are particularly advantageous, with substantial pumped storage sites being available close to the main load centres. Pumped storage facilities, for peak-power supply on a daily/weekly basis, are economically attractive due to their low investment costs and the low marginal prices of the energy consumed in the pumping cycle. The investment costs in the industrial South East would be in the range of US$ 200-260 per kW installed (1981 prices), including interest charges during construction. There would also be a minimum saving of US$ 150 per kW in transmission costs, which would add significantly to the total benefits(195-197).

Electrical Energy in Brazil

The general economic decline which occurred in Brazil and precipitated the 1964 revolution, was also mirrored by a decline in the electric power industry. Operating with tariffs based on the historic cost of investments, most of the enterprises involved were in the process of economic and financial destruction. The standard of service offered was inadequate and suffering from stagnation (see p.119). The transmission and distribution networks were not expanding to meet needs and, in some areas, there arose the paradox of energy being available but with no means of supplying it to the consumer. In June 1964, the revolutionary government defined a new policy for the electric power industry, outlining the courses of action to be taken

Table II.v : Installed Generating Capacity in Brazil

Year	Hydro GW	Hydro %	Thermal GW	Thermal %	Total GW	Annual Increase GW	Annual Increase %
1962	4.126	72.0	1.603	28.0	5.729		
1963	4.479	70.5	1.876	29.5	6.355	0.626	10.9
1964	4.894	71.5	1.946	28.5	6.840	0.485	7.6
1965	5.391	72.7	2.020	27.3	7.411	0.571	8.3
1966	5.524	73.0	2.042	27.0	7.566	0.155	2.0
1967	5.787	72.0	2.255	28.0	8.042	0.476	6.3
1968	6.183	72.2	2.372	27.8	8.555	0.531	6.4
1969	7.857	76.6	2.405	23.4	10.262	1.707	20.0
1970	8.828	78.6	2.405	21.4	11.233	0.971	9.5
1971	10.244	80.9	2.426	19.1	12.670	1.437	13.0
1972	10.756	81.4	2.450	18.6	13.206	0.536	4.2
1973	12.500	81.0	2.936	19.0	15.436	2.230	16.9
1974	13.757	81.3	3.162	18.7	16.919	1.483	9.6
1975	16.184	82.7	3.385	17.3	19.569	2.650	15.7
1976	17.675	83.9	3.385	16.1	21.060	1.491	7.6
1977	19.038	84.1	3.599	15.9	22.637	1.577	7.5
1978	21.576	85.6	3.627	14.4	25.203	2.566	11.3

Source : ELETROBRAS 1978 report, p.10.

by the authorities responsible for the industry. The new policy was based upon existing laws and suplemented by new standards of administration. Its directives were :

- general adoption of economic costing (Article 180 of the Código de Aguas and decree no.41019 Article 164).

- adequate levels of protection of investments against inflation, aimed at recovering the confidence of investors and prevention of the systematic destruction of capital(198).

Since 1964, there has been a massive expansion in the installed capacity and gross electric energy production in Brazil (see tables II.v and II.vi). From 1962 to 1977 the installed capacity rose from 5.7 GW to 22.6 GW, and the gross energy production rose from about

Table II.vi : Gross Energy Production in Brazil, 1962-1978

Year	Hydro TWh	Hydro %	Thermal TWh	Total TWh	Annual % increase
1962	20.662	76.1	6.496	27.158	-
1963	20.728	74.4	7.141	27.869	2.6
1964	22.097	75.9	6.997	29.094	4.4
1965	25.515	84.7	4.613	30.128	3.5
1966	27.906	85.4	4.748	32.654	8.4
1967	29.189	85.3	5.049	34.238	4.8
1968	30.550	80.0	7.631	38.181	11.5
1969	32.692	78.5	8.956	41.648	9.1
1970	39.863	87.7	5.597	45.460	9.1
1971	43.274	84.9	7.714	50.988	12.2
1972	51.407	90.2	5.588	56.995	10.5
1973	58.289	90.2	6.352	64.641	13.4
1974	65.492	90.5	6.904	72.396	12.0
1975	73.836	92.0	6.457	80.293	10.9
1976	82.361	92.9	6.259	88.620	10.4
1977	92.430	91.9	8.187	100.617	13.5
1978	100.111	90.1	10.999	111.110	10.4

Source : ELETROBRAS 1978 Report, p.12.

27 TWh in 1962 to over 100 TWh in 1977. A percentage increase of 295% and 270% respectively. Comparing the percentage annual increase of both installed capacity and production, it would appear that while both are increasing they are not in step. Over the period considered, the total percentage increase in installed capacity is greater than that for the total percentage increase in electricity production; the capacity factor has declined. This is most likely as a result of a reduced transmission loss.

Table II.vii : Transmission Lines 1970-1978 (km)

Year	230 kV	345 kV	440 kV	500 kV	Total	% increase
1970	11 316	2 681	1 096	-	15 099	-
1971	11 429	3 330	1 096	-	15 855	5.0
1972	11 493	3 456	1 096	-	16 045	1.1
1973	12 005	4 081	2 329	-	18 415	14.7
1974	12 725	4 431	2 708	360	20 224	9.8
1975	13 409	4 962	2 982	360	21 713	7.3
1976	14 714	5 301	3 225	1 693	24 933	14.8
1977	16 234	6 204	3 225	3 089	28 752	15.3
1978	18 269	6 904	3 514	5 310	33 997	18.2

Source : ELETROBRAS 1978 Report

The increase in installed capacity has been due to the increase in hydroelectric generating capacity. The thermal generating capacity has only increased very slowly from 1962 to 1977. This has been due to the policy of use of renewable energy resources and, since the oil crisis, the reduced use of petroleum derivatives for electricity generation (see p.33). Most of the thermal generation is from the isolated generating systems of Amazonia, or from the use of thermal stations in the southern regions at times of low river flows. The hydroelectric percentage of installed capacity rose from 72.0% in 1962 to 84.1% in 1977(199).

Table II.viii shows the breakdown, by region, of the installed generating capacity in Brazil in 1978. Except for the northern region, hydroelectric capacity is dominant. In the industrial South East, 93.6% Of installed capacity is hydroelectric. In the Southern region the percentage is lower due to the existance of coal-fired power stations in Santa Catarina and Rio Grande do Sul. It is interesting to note that the estimated figure for the 1978 installed capacity, 25.203 GW, as quoted by ELETROBRAS(200), is some 8% higher

Table II.viii : Installed Capacity, by Region

Region	Installed Capacity (GW)			
	Hydro	% Hydro	Thermal	Total
North	-	0	0.259	0.259
North East	2.153	88.4	0.282	2.435
South East/Centre West	16.887	93.6	1.153	18.040
South	2.003	77.2	0.593	2.596
Total	21.043	90.1	2.287	23.330

source : ELETROBRAS, Plano 95, 1979, p.2.1

than the actual installed capacity quoted in the Plano 95(201). The difference is mainly in installed thermal capacity. From Table II.ix,

Table II.ix : Programme of Works in Progress

Year	North	North East	South East	South
1979	-	UTE Salvador UTE São Luís Sobradinho P.Afonso IV	São Simão C A.Vermelha C E.da Cunha R A.S.Oliveira R Igarapé	UTE J.Lacerda E Itaba C
1980	-	-	Itumbiara Angra I	Salto Osório C Salto Santiago Foz do Areia
1982	-	B.Esperanca C	Emboração	-
1983	Tucuruí	-	T.Irmãos	Candiota
1985	-	Itaparica	-	-
1986	-	-	Angra II	-
1987	-	-	Angra III	-

C Complementation R Repair E Expansion

Source : ELETROBRAS, Plano 95, 1979, p.2.1

it can be seen that three thermal power stations are expected to be operating in 1979. If one, or all of these had originally been scheduled for completion in the last quarter of 1978 this would explain the difference in the figures. The discrepancy in the hydroelectric figures can be explained by the delay of entry into operation of two units of UHE São Simão(202).

Electricity Consumption

Table II.x : Electricity Consumption, by Consumer 1962-78

Year	Indust. TWh	Resid. TWh	Comm. TWh	Others TWh	Total TWh	Annual % increase
1962	11.269	4.528	2.944	3.116	21.857	-
1963	11.555	4.843	3.051	3.169	22.618	3.5
1964	11.958	5.123	3.126	3.314	23.521	4.0
1965	12.108	5.320	3.372	3.468	24.268	3.2
1966	13.597	5.739	3.570	3.588	26.494	9.1
1967	13.861	6.327	3.824	3.976	27.988	5.6
1968	16.116	7.070	4.325	3.888	31.399	12.2
1969	17.266	7.763	4.778	4.707	34.514	9.9
1970	19.613	8.522	5.286	4.889	38.310	11.0
1971	22.302	9.398	5.802	5.534	43.036	12.3
1972	25.056	10.117	6.525	6.179	47.877	11.2
1973	29.714	11.159	7.377	6.852	55.102	15.1
1974	33.678	12.301	8.310	7.649	61.938	12.4
1975	37.790	13.507	9.176	8.452	68.925	11.3
1976	43.621	14.894	9.927	9.039	77.481	12.4
1977	50.189	17.112	10.525	10.018	87.844	13.4
1978	55.817	18.968	11.670	11.292	97.747	11.3

Source : ELETROBRAS 1978 Report,p.9.

During the "recovery period", when the electric power industry was recovering from the stagnation of the 1950s and early 1960s, industrial consumption accounted for approximately 50% of the total Brazilian electrical energy consumed. From 1970 this has gradually risen to 57% in 1977. Increase in industrial demand was for a variety of reasons. The early 1970s were the years of the "economic miracle"(203), with an accompanying industrial expansion. Expansion of the elctrical power industry also aided industrial expansion. In the later 1970s, the policy of import substitution was more forcibly enacted, with a consequent expansion of new industries and their energy requirements(204).

However, all classes of consumer showed an increase in consumption. Residential consumption rose by 278% over the period 1962-1977, but maintained its percentage of the total at about 20%. Commercial consumption is lower, maintaining about 13% of the market. Table II.xi shows the evolution of the rates of increase in consumption of electrical energy by region. The large increase by industry in the North and Centre West regions, in 1976, is responsible for the increase in total Brazilian consumption. The increase in the Centre West region was due to expansion of the ceramic industry(205). Increase in the North, North East and Centre West regions has consistently been above the national average, but has not had a significant effect on the overall increase in consumption, because the demand is predominantly in the highly populated, highly industrialised South East and South regions of Brazil.

Not only is most of the installed capacity concentrated in the South East region (see table II.viii), that region is also the location of the main consumer market. The close relationship between industry and hydroelectric power development in Brazil has been a long one. Hydroelectric power was first developed to satisfy industrial needs (see p.74). The accelerated industrial development in the South East was only made possible because of the abundance of power available following the completion of the Serra do Mar project in 1926 (see p.94). The energy infrastructure provided in the North East of the country was the essential basis for all industrial

Table II.xi : % rate of increase of consumption by region, 1976-1979

Regions	1976	1977	1978	1979
NORTH				
Total	19.7	14.9	16.0	15.3
Residential	12.7	18.0	17.4	21.6
Commercial	13.4	16.2	17.6	22.5
Industrial	37.4	12.0	15.0	14.0
NORTH EAST				
Total	16.9	16.5	17.5	13.1
Residential	14.9	18.1	14.6	15.9
Commercial	16.1	16.2	14.6	15.0
Industrial	19.1	18.7	19.2	12.7
SOUTH EAST				
Total	13.1	11.4	10.6	11.7
Residential	11.5	14.7	9.7	9.6
Commercial	8.4	2.0	6.9	8.4
Industrial	16.0	12.9	12.2	13.6
SOUTH				
Total	17.1	16.4	9.2	14.5
Residential	14.0	15.8	8.6	12.9
Commercial	14.2	15.7	4.3	12.2
Industrial	21.6	16.8	10.8	14.6
CENTRE WEST				
Total	16.9	20.4	16.5	16.1
Residential	18.8	17.9	18.1	17.4
Commercial	12.6	19.7	17.8	16.2
Industrial	31.0	28.8	20.3	17.0
BRAZIL				
Total	14.2	12.8	11.5	12.4
Residential	12.4	15.4	10.6	11.3
Commercial	10.1	6.3	8.1	10.5
Industrial	17.1	14.1	13.0	13.7

Source : Anon., Mundo Elétrico, Ano 21 (246), 22-25.

development programmes, and industrial development in Minas Gerais rose above stagnation once there was a reliable supply of energy(206).

Electrical power consumption in Brazil has grown steadily at very high rates for a long time, with a 10.4% annual increase over the period 1948-1978, and 12.1% for the 1970s(207).

Table II.xii : Net consumption of electricity per capita

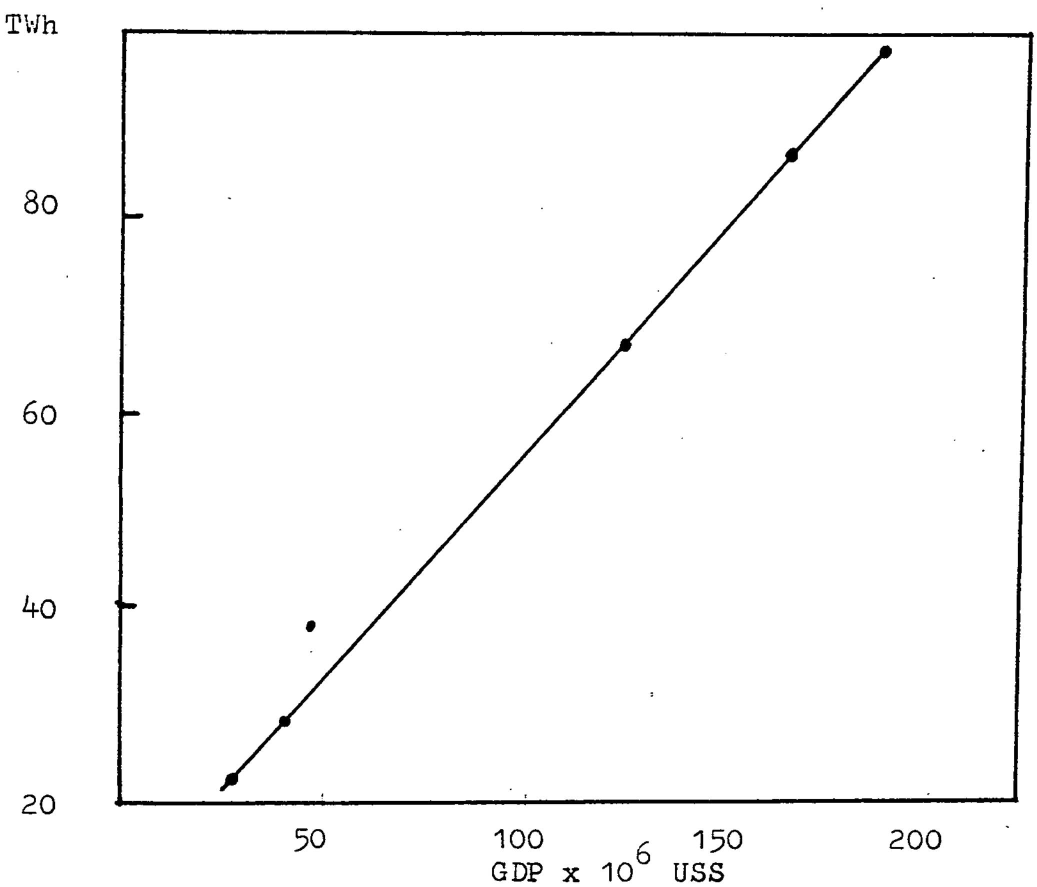
Units : KWh

	1955	1958	1960	1962	1965	1970*	1975*	1980*
Brazil	188	245	263	294	296	407	549	760
SE Brazil	315	428	485	545	562	827	1078	1365
Rest of Brazil	98	114	105	114	107	108	165	309

* Estimated

Source : Canambra Engineering Consultants Ltd. "Power Study of South Central Brazil, 1969.

Figure 2.4 : Variation of Electricity Consumption with GDP



Source : GDP - Yearbook of National Account Statistics, Vol.II, UN, 1979, p.101. Consumption - ELETROBRAS 1978 report.

From figure 2.4, a linear relationship can be observed between electricity consumption and Gross Domestic Product (GDP). The point which is not on the line represents an above average increase in electricity consumption for 1970 as a result of a 20% increase of available generating capacity over the previous year (see table II.v).

Market Forecasting

The structure and distribution of national and regional income give important indicators for the forecasting of electricity consumption and the overall expected behaviour of the market. Estimates of the future increase in the economy have been based on traditional econometric models, considering factors such as the formation of capital, balance of payments and productivity of the work force. In view of the limitations of such models in the actual world economic context, reliance has been placed on more qualitative studies based on scenarios and other forecasting techniques(208).

For the purpose of calculation of the forecasts of the electricity market, the rate of increase of GDP, for the high projection, was taken as 10% per year for the periods 1974-1979 and 1979-1990. In the case of the low projection, a rate of increase of 8% was used(209)*. There is however, an anomaly in the figures used. Figure 2.4 clearly demonstrates a linear relationship between electricity consumption and GDP, all figures being obtained from reliable sources(211,212), but according to the figures in the Plano 95, the mean real increase in the GDP, from 1974 to 1978, was 6.3% per year, and in spite of that, the increase in consumption of electricity was maintained at over 12% per year. This would suggest a non-linear relationship over the whole period considered *.

Although the economic references used by the Departamento de

---

* For total energy balance calculations, including petroleum importation, the MME is also using a GDP correlation, but is making three projections based on increases in the GDP of 5%, 7% and 9%, and using the intermediary rate of 7% as the base(210).

* According to the World Bank, the average annual growth of GDP in Brazil from 1970-1977 was 9.9% (213).

Table II.xiii : Increases in Electricity Consumption and GDP

Period	% increase in electricity consumption	% increase in GDP
1970-74	12.9	12.2
1974-78	12.4	6.3

Source : ELETROBRAS, Plano 95, 1979, p.2

Estudos do Mercado (DEME) adopt a figure of 8% or 10% for the rate of increase of GDP in their estimates, it can be observed in the Plano 95, that if the rate of increase in the Brazilian economy is maintained at the growth rate of GDP of 6-7% per year, the requirement for increase in generation will be at a mean rate of 12.7% per year, in order for the dynamism of the industrial electricity market to be maintained in the face of increased substitution of petroleum derivatives by electricity. The exception to this relationship will be in the North region, where large, localised, industrial loads are forecast to be developed in the mid-1980s.

The forecast produced by DEME for electrical energy consumption until 1995 is shown in table II.xiv. From this, it can be seen that until 1983, the growth rate of consumption will be greater than in the subsequent period up to 1995. This is explained by the nature of the growth of the economy. Certain kinds of industry, especially the energy intensive such as the electrochemical and electrometallurgical industries, will be responsible for major increases in energy consumption when they are established. From 1977-1995, the total Brazilian annual consumption is expected to rise from 87.8 TWh to 438.7 TWh, with a corresponding rise in the annual per capita

Table II.xiv : Forecast of electricity consumption by region until 1995 (TWh).

Year	Brazil	North	N.East	S.E & C.W.	South
1977	87.829	1.307	10.203	65.478	10.841
1983	167.726	3.803	23.820	117.004	23.099
	169.436 *	5.381 *	23.952 *		
1995	438.727	27.572	67.203	278.559	65.394
	440.662 *	28.154 *	68.555 *		

Source : DEME, Referências Econômicos para o Planejamento, 1979, and

* ELETROBRAS, Plano 95, 1979, p.1.2

consumption from 755 kWh to 2 490 kWh - a strong indication of the qualitative alterations in the economy and standard of living.

Growth in the South East region will be slower than in the other regions by virtue of the accelerated industrial development occurring elsewhere. The contrast will be greatest in the North, where consumption is expected to rise by 625% from 1983 to 1995.

Table II.xv : Forecast % increase in electricity consumption, 1977-1995

	Brazil	North	N.East	S.E. & C.W.	South
Residential					
1977-83	9.6	12.6	13.7	8.5	11.0
1983-95	6.5	9.1	6.2	6.3	7.0
Industrial					
1977-83	12.6	33.3	15.5	11.4	15.6
1983-95	10.1	51.7	11.7	8.6	11.1
Total					
1977-83	11.7	18.8	14.5	10.5	14.4
1983-95	8.7	19.1	9.6	7.8	9.3

Source : DEME, Referências Econômicas para o Planejamento, 1979.

Of this increase in the North, 51.7% will be as a result of increased industrial consumption. The concentration of large blocks of electrical energy in the less developed regions is the policy of the Brazilian Government with the intention of reducing some of the inequalities between regions(214).

By 1976, of the 450 dams which have been constructed in Brazil since 1901, nearly 150 have been for hydroelectric power generation. Many of these dams are small, under 15 m high, and the power output from the associated hydroelectric power stations, is low. Some are no longer operating(215). In 1974, the number of Brazilian hydroelectric power stations in operation with an installed capacity greater than 15 MW, was 54, and a further 12 were under construction. The installed capacity was 9.73 GW, with a further 14.29 GW under construction(216). By 1978, the installed hydroelectric potential was 21.58 GW, and by 1985, this is planned to be approximately doubled to 43.48 GW, and increased further to 62.81 GW by 1990(217)(see table II.xvi).

Table II.xvii shows the new construction works, scheduled to 1990, for the interconnected systems. This will add a further 18.4 GW. The major Brazilian hydroelectric power stations are shown in figure 2.5.

Financing in the Electrical Power Industry

Until the 1950s, the electricity supply industry in Brazil was in the hands of the private sector, and, so, responsible for financing itself. With the advent of government intervention in the industry (see p.127) it was necessary to formalise its financing.

From 1943 to 1953, the installed capacity increased by an average of 1.95% per year, whereas production increased at an annual

Table II.xvi : Growth of Installed Capacity, 1978-1990

	Installed Capacity MW			Annual Increase in Capacity					
				Programme in Progress			New Works		
Year	Hydro	Thermal	Total	Hydro	Thermal	Total	Hydro	Thermal	Total
1978	21 575	3 654	25 229	-	-	-	-	-	-
1979	24 134	4 332	28 466	2 559	678	3 237	-	-	-
1980	27 265	5 086	32 351	3 147	754	3 901	-	-	-
1981	32 151	5 170	37 321	4 886	84	4 970	-	-	-
1982	33 097	5 175	38 272	976	5	981	-	-	-
1983	35 967	5 400	41 367	2 530	165	2 695	340	60	400
1984	40 237	5 560	49 042	3 390	160	3 550	880	-	880
1985	43 482	5 560	49 042	2 890	-	2 890	355	-	355
1986	48 175	6 805	55 520	1 730	1 245	1 945	3 632	320	3 952
1987	53 047	8 370	61 417	710	1 245	1 945	3 632	320	3 952
1988	56 127	8 370	64 497	-	-	-	3 080	-	3 080
1989	58 952	8 370	67 322	-	-	-	2 825	-	2 825
1990	62 807	8 370	71 177	-	-	-	3 855	-	3 855
Interconnected	-	-	-	22 808	4 231	27 039	18 085	320	18 405
1/2 Itaipu	6 300	-	6 300	6 300	-	6 300	-	-	-
Isolated	-	-	-	-	105	105	385	60	445
Total	69 107	8 370	77 477	29 108	4 336	33 444	18 470	380	18 850

Source : Plano 95, p.7

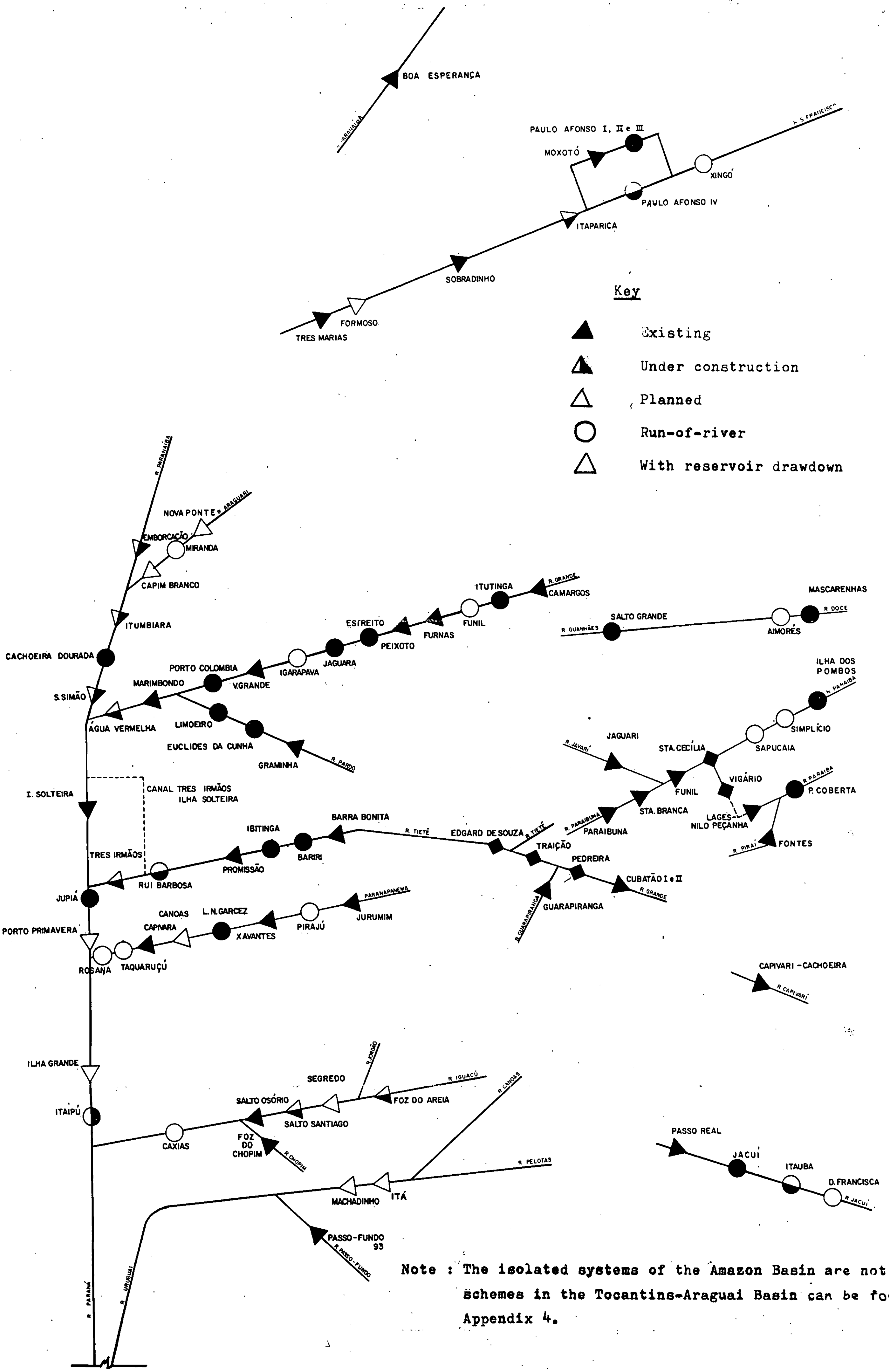
Table II.xvii : Programme of New Power Stations for Operation 1986 - 1990

Region	Year of Starting	Power Station	Units Programmed MW	Capacity Programmed MW
South	1986	Ilha Grande	14 x 100	1 400
		Segredo	3 x 350	1 050
		D. Francisca	2 x 62	124
	1987	Candiota (T)	-	320
	1988	Machadinho	4 x 265	1 060
	1989	Salto Caixas	4 x 250	1 000
SE/CW	1983	Santa Branca	2 x 30	60
		Nilo Pecanha	4 x 65	260
	1984	Taquaracu	3 x 100	300
		Rosana	3 x 80	240
	1985	Porto Primavera	11 x 100	1 100
		C. Dourada	3 x 85	255
	1986	C. Magalhaes	2 x 55	110
		Fecho da Onca	2 x 125	250
		Corumba	2 x 150	300
		Nova Ponte	2 x 168	356
		Sapucaia	3 x 136	408
	1987	Miranda	2 x 211	422
		Canoas	2 x 100	200
	1988	Aimores	3 x 100	300
		Igarapava	3 x 50	150
	1989	Sao Felix	4 x 265	1 060
		Capim Branco	2 x 208	416
		Simplicio	1 x 119	119
		Descalvado	3 x 55	165
	1990	Formoso	2 x 100	200
		Funil	2 x 82	164
		Peixe	4 x 184	736
		Ourinhos	2 x 25	50
		Eldorado	3 x 30	60
N.East	1987	Xingo	5 x 500	2 500
North	1987	Tucurui (units 9 & 10)	2 x 330	660
TOTAL (incuding additional load capacity)				18 405

Note : This was the schedule as planned in 1979, UHE Itaipu was assumed to be fully operational. The economic situation in Brazil since 1979 has resulted in a number of changes.

Source : ELETROBRAS "Plano 95", 1979, table 3.1

Figure 2.5 : Schematic Representation of the System of Brazilian Hydroelectric Power Stations



Note : The isolated systems of the Amazon Basin are not shown. The schemes in the Tocantins-Araguai Basin can be found in Appendix 4.

Source : Departamento de Estudos Energeticos, ELETROBRAS, 1977, and Plano 95, 1979.

average of 2.56%. This caused a gradual reduction in the available reserve of generating capacity until it compromised the reliability of the system. By the beginning of 1953, the national aggregated deficit with respect to demand was 100 MW, and it is reasonable to assume that most of this occurred in the South East. In many states, substantial portions of their budgets were put towards the cost of electrification works, but this was still inadequate to permit them to cover even emergency programmes aimed at reducing the deficiencies of electricity supply in their own territories. The state of Rio Grande do Sul created a supertax upon nearly all the state taxes, the "taxa de eletrificação", in order to finance its electrical power industry.

Expansion in the private sector was little better. The rates of industrialisation and urbanization were higher than had been estimated and, at the same time, there were difficulties in the importation of equipment in the inflationary climate which was beginning to prevail. The electrical power industry was one where its ability to invest was reflected by its profits. These were based, by law, on the historic value of the investments, which limited the interest for private initiative(218).

The use of historic value had been laid down in the Côdigo de Aguas in 1934, when it allowed a 10% return on a power company's investment. The return was calculated on a capital base evaluated at the original cost, and the basic rate was set so as to yield that return. However, the original, or historic, cost of the company's investment was continuously eroded by inflation, and, without provision for a periodic correction to the value of the company's assets, it became an inadequate basis for the calculation of a fair return. This was the root cause behind the rate problem experienced by 'The Light', when it refused to invest in the sector, because of the low rate it had to charge for the electricity it produced(219) (see p.121).

The foreign capital enterprises, which, at the time, supplied electricity to the richest areas of Brazil, and which could guarantee income through the controlled interest from exchange conversion, were disinclined to undertake the urgently needed expansion of the electrical power industry by producing new capital from abroad. As a result, the Federal Government had to resort to capitalization by a fiscal route. This was proposed by the Congresso Nacional in 1953.

As a result, law no.2308, of 31 August 1954, was passed creating the Fundo Federal de Eletrificação (FFE, Federal Electrification Fund) and the Imposto Unico sobre Energia Elētrica (IUEE, special electricity tax). The law determined that 40% of the IUEE would be for use by the Federal Government, and 60% would be given to the states and towns for the expansion of the electrical power industry, corresponding to quotas and criteria as set out in the special law. The Banco Nacional de Desenvolvimento Ecômico (BNDE) was authorised to use the Federal resources from the FFE in order to finance the more urgent programmes, and to allocate, to the various states, sums in accordance with their quotas for the same purpose.

The BNDE had been established in 1952 as an independent federal agency, subordinate to the Ministērio da Fazenda, to serve as a financial instrument for the execution of government policy. At the same time, the Plano Nacional de Eletrificação was proposed, with the intention of programming works of construction, unification of frequency, and stimulation of electrical material industries. This plan was not adopted, but the BNDE was entrusted with administration of the FFE for five years.

Prior to the creation of the FFE, the BNDE had been involved in supplying finance to the electricity concessionaires, including external loans, in the name of the Tesouro Nacional (National Treasury). With time, the federal 40% of the IUEE, operated by the BNDE, did not generate sufficient returns with which to meet the increasing outlays, because the taxations of the IUEE were not corrected to absolute values at the same level as the increase in the cost of works.

As a result it was necessary to complement the collection of the IUEE with the financial resources of the BNDE itself, especially from the Fundo de Reaparelhamento Econômico (Economic Reconstruction Fund). When state enterprises proposed construction works and applied for federal resources, they were only granted such funds on condition that there was the greatest possible contribution from the Fundos Estaduais de Eletrificação (State Electrification Funds). If resources were required for private projects, the bank could only supply funds from its own resources. as private application to the resources of the FFE were prohibited.

However, private initiative still received federal support by means of loans. In fact, practically all the significant loans for electrification which were granted after 1953 had the support of the BNDE, either directly, with financial resources or active participation, or indirectly, with the payment of guarantees either in the name of the BNDE or the Tesouro Nacional (National Treasury).

The establishment of ELETROBRAS in 1962, and the later consolidation of the financial structure of the electrical power industry by the strenghthening of the FFE and the creation of an Empréstimo Compulsório (Compulsory Loan), enabled the BNDE to remove itself from financially supporting the electrical sector in order to concentrate on other development areas. In addition, there was a re-assessment of the fixed assets of the concessionaires, and this re-evaluation was incorporated into the cost of services and the tariffs(220).

When ELETROBRAS came into existence, the financing of large projects depended on national funds. With the development of national technology and industry, in medium scale undertakings, such as UHE Boa Esperança and UHE Cachoeira-Capivari, national financing was as high as 82%. In 1964, the director of ELETROBRAS, Manual Pinto de Aguiar, stated that the expansion of the electrical energy sector, on which Brazil's future depended, hinged on the effort of the Brazilian people. International loans, although important, he considered as only supplementary and complementary to the national effort(221).

In order to sustain the expansion of the electrical power industry law no. 4156, of 28 November 1962, instituted the Empréstimo Compulsório in favour of ELETROBRAS. This loan was to attract interest of 12% per year, and would be recoverable after ten years. The same law redefined the method of collection of the IUEE, introducing differential quotas for rural, residential and industrial consumers, and adopting the tariff as the base of the calculation, to be recalculated each quarter. The introduction of this concept of an ad valorem tax represented an important mechanism for the prevention of the reduction in value of the IUEE, as had occurred between 1954 and 1962, as a result of the tax originally being set at a fixed value per kWh and thus gradually eroded by inflation. According to law no.4156, 40% of the Imposto Unico belonged to the Federal Union, and was credited to the FFE, 50% went to the states, Distrito Federal and territories, and the remaining 10% went to the municipalities. All of it was for use in the electrical power industry expansion plans, which were elaborated by ELETROBRAS.

Later legislation required the tariff to be adjusted quarterly, based on the data from the previous month. The IUEE tax was set at 50% of the tariff for the residential consumers, 60% for the commercial consumers and 16% for industrial consumers whose monthly consumption was less than 2 000 kWh. Consumers exempt from the payment were those served exclusively by thermal generation, and those whose monthly consumption was less than 30 kWh.

Further legislation, again in favour of ELETROBRAS, gave validity to the Emprêstimo Compulsório until 31 December 1983.(As yet there is no information on what will happen after that date). The tax falling upon the industrial consumers with a monthly consumption greater than 2 000 kWh is based on a quota of 32.5% to be applied to the tariff. The sum is recoverable in a period of 20 years, and the annual interest rate is 6%. Monetary corrections are made according to the re-evaluation index of the fixed assets of the enterprises. For those industries with a very high consumption of electricity, a reduction of the loan is made as a function of the relationship between the payment for electricity and the value of sales. The policy of rationalization of the use of energy, adopted at the end of 1977, makes the Emprêstimo Compulsório payment heavy for those autoproducers with an installed capacity for electricity production greater than 500 kW, if they are using petroleum derivatives for fuel when an alternative supply of power is available from the local concessionaire(222,223).

The system of Empréstimo Compulsório has been very unwieldy and, in 1975 it was modified to reduce administrative tasks and the volume of paper. At that time there were in circulation approximately 7.3×10^6 ELETROBRAS bonds, with a total of 28×10^6 titles issued in 34 series of different values - representing 63 tons of paper. With the launching of three or four series a year, the increase will reach 2×10^6 titles annually, with approximately 110×10^6 coupons (cupons de juros) in circulation. As a result, the system has been computerised and the interest paid will be recorded on the reverse side of the shares. Previously, the maximum value per title was Cr$ 10 000, but this has been increased to Cr$ 50 000 under the new system(224). Generation of finances by this method, has, however, not been sufficient.

In the 1968 ELETROBRAS report, the intention to double the installed capacity in Brazil in the next few years was expressed at the same time as the admission of financial problems requiring study. The estimated deficit for the Plano Energético Trienal was Cr$ 500×10^6 (1968 prices). As a consequence of ELETROBRAS's investment in pioneering areas, it became necessary to depend on a third source of funding. This was obtained in the form of loans totalling Cr$ 224×10^6 in 1968, with an operational income of only Cr$ 139×10^6, and a further Cr$ 224×10^6 from the FFE. This proved unsatisfactory, as the loans had to be repaid by means of amortization and redemption, with inevitable extra financial burdens on the already limited resources(225).

Brazil had already turned to foreign sources of financing. The two major examples of this being the loan to FURNAS from the World Bank, and the loan from the United Nations Development Fund for the CANAMBRA studies. In fact, FURNAS has always relied upon the World Bank as its principal source of external finance. The first loan in 1958, for US\$ 73×10^6 (1958 prices), was for the construction of UHE Furnas and the associated transmission system (see p.101). However, this loan was only to cover importation of equipment, materials and services which had to be paid for in foreign currency.

In 1965 and 1966, FURNAS received two further loans from the World Bank, totalling US\$ 96×10^6 (1966 prices), for the financing of UHE Estreito and its transmission system. For the first time, in Brazil, the contracts included clauses allowing the use of these resources to purchase equipment on the internal Brazilian market with payment in national currency. For UHE Marimbondo the investment was US\$ 287×10^6, of which US\$ 106×10^6 came from the World Bank and the rest from local resources. The loan was for engineering services and acquisition of materials and permanent equipment.

In 1969 the World Bank proposed a new scheme of joint financing, to the Brazilian Government, involving some European countries, the USA, Canada and Japan. All these had some interest in partly financing the materials and equipment, which they would be allowed to supply, if they could meet the criteria of international competition. This proposal was accepted in principle by the MME, the Ministério da Fazenda, ELETROBRAS and FURNAS, subsequent to a meeting in Paris, in March 1970, between the countries interested, the World Bank and Brazil.

Present at the Paris meeting were delegations from West Germany, Belgium, Canada, the USA, France, Great Britain, Italy, Japan, Sweden and Switzerland, together with representatives from Holland and Spain. The meeting reached an accord in which each participating country was to finance 50% of the orders it won after international competition. These orders would individually amount to less than US$ 200 000, but combined would total US$$1x10^6$ (1970 prices). The World Bank was to finance the other 50%, in addition to being responsible for the financing of 100% of the remaining purchase orders.

The credits to be conceded by the co-participating countries had to meet the following conditions :

i. a minimum period of amortization of ten years, and

ii. a maximum period of debt of eighteen months, counted from the date of shipment of equipment.

For its part, the World Bank was obliged to adjust, within certain limits, the scheme of amortization of its loan, so that the total of the annual amortizations to be paid to the World Bank and co-financers would be approximately equal to that which would be paid in the case of the World Bank being the sole financer. In the opinion of FURNAS, this kind of financing carried an excessive administrative load, in terms of negotiating and operating numerous loans of different origin destined to the financing of a single project(226).

The opening up of the world financing market had much to do with the evolution of this new method of payment for large scale power industry projects in Brazil. The most industrially developed countries, such as Japan and Germany, having undergone a large expansion, were beginning to have problems with the placing of their products. The competition for new markets had become increasingly intensive with the advent of Japan on the scene as a major producer and strong competitor(227).

Although the mechanism for external borrowing had been established by 1974, 80% of the financing of the Brazilian electrical power industry was internal, the foreign contribution being US$250-300x$10^6$ (1974 prices). Such credits, although only 20% of the total, were, however, vital to the structure of the financial sector. By this time, the sector depended upon three types of provision :

i. the external exogenous, resulting from loans obtained jointly from international financing agencies and suppliers of equipment,

ii. the internal exogenous, which was provided from Federal and state budgets, and

iii. the endogenous, generated by the sector itself.

For UHE Paulo Afonso IV, for example, ELETROBRAS provided Cr$ 4.6x10^9 (1974 prices), and the other 20% was provided jointly by the World Bank and the Inter American Development Bank(228).

Brazil, now in the midst of another economic crisis, has been strongly affected by the world recession. It has large outstanding loans, principally being used to finance the power industry expansion masterminded by ELETROBRAS. The cruzeiro has been devalued regularly over the last few years (see app.2), but the maxi-devaluation of 30%

in December 1979 created large problems for the electrical power industry. Although ELETROBRAS had expected there to be a major devaluation of the cruzeiro, against the US dollar, it had been expected that this would have taken place gradually over two or three years, and not in one large move.

In 1978, the company borrowed a large amount of foreign capital. Its total investments were US\$ 6.0×10^9. Equipment and service imports rose to US\$ 1.0×10^9, and there was an extra US\$ 1.4×10^9 in new overseas loans, hence the net inflow of foreign loans was US\$ 2.4×10^9 in 1978 (1978 prices). In terms of total loans, ELETROBRAS owed approximately US\$ 6.5×10^9 to the international banks, and the maxi-devaluation of 30% induced a severe financial crisis within the company(229).

In 1976, ELETROBRAS received three loans from the International Development Bank (IDB) - US\$ 64×10^6 for UHE Salto Santiago, US\$ 35×10^6 for the expansion of the UHE Paulo Afonso transmission system and US\$ 74×10^6 for the construction of UHE Foz do Areia (1976 prices)(230).In 1977, the IDB gave a loan to CEMIG of US\$ 69.8×10^6 (1977 prices) for the construction of UHE Emboração. At that time, the total cost was estimated at US\$ 732×10^6, of which the IDB had supplied 9.5%, CEMIG 45.7% and ELETROBRAS 33.3%.

From the 1978 ELETROBRAS financial statement, it is interesting to note that the contribution of the IUEE was lower than in the previous year, but the external financing rose from Cr\$ 5 542×10^6 in 1977, to Cr\$ 12 366×10^6 in 1978 (1977 and 1978 prices respectively). At the end of the 1978 financial year, ELETROBRAS had current loans from 16 foreign organizations, consisting of US\$ 1.0×10^9, DM 0.3×10^9

and Yen $15.0x10^9$ - a total of Cr$ $29.0x10^9$ (1978 prices). At that time, the capital stock of the company was valued at Cr$ $36x10^9$ (231).

During 1979 the situation deteriorated, with ELETROBRAS having to seek a US$ $400x10^6$ syndicated loan, without government guarantee. It was thought to be the first time that this had happened. The funds were earmarked for the purchase of 'The Light'(232). With a soaring Brazilian trade deficit of US$ $988x10^6$ in 1978(233), ELETROBRAS was lucky to raise the US$ $400x10^6$ medium term loan which it required. This demonstrated a marginal improvement in Brazil's creditworthiness in the Euromarkets(234), and by March 1979, the situation had improved further, with Brazil able to renegotiate the terms of a US$ $250x10^6$ loan, originally taken out in 1977, with a banking consortium led by the Bank of America(235).

However, at the end of March, the Brazilian Government, as an anti-inflation measure, put an absolute ceiling on foreign borrowing by state run concerns of US$ $3.0x10^9$. This was 33% less than in the previous year, and a reduction of US$ $800x10^6$ on the original loan forecast. It was also decreed that there be a new cut from the public spending in the Federal budget of US$$2.0x10^9$. This included US$ $350x10^6$ from the Economic Development Fund, which is used in the fields of education, transport and energy. OPEC price rises will, however,add a further US$$400x10^6$ to Brazil's annual bill for imported crude oil, and raise the total to nearly US$ $5.0x10^9$ (236). Yet, despite the ceiling on foreign borrowing, in May 1979 the Swedish firm ASEA was awarded a US$ $900x10^6$ contract for the HVDC transmission lines for UHE Itaipu. However, 50% of the equipment is to be manufactured locally(237), and support for this contract was set up through a large financial package of Eurocurrency loans and export credit facilities(238).

Two major projects which are absorbing both internal and external resources are UHE Itaipu and UHE Tucuruī. The costs for both are escalating but, as both are priority projects, funds are continuously being injected into them, at the expense of other projects. Their final costs are expected to be billions of dollars (239,240).

As a result of Brazil's balance of payments deficit and inflation, both of which are reducing the country's credit standing, the financial situation of ELETROBRAS remains precarious, especially with such large sums of money continuously on loan.

CHAPTER 3

Development of the Brazilian Electrical Power Industry

"There are one hundred and forty thousand Brazilians directly employed in the Brazilian electrical energy sector. There are two hundred thousand others who work on the construction of new schemes and equipment"(241). In 1978, investments in the electrical energy sector were Cr$ 70.8×10^9(1978 prices) and the total assets of the companies in the electrical power industry increased to Cr$ 400×10^9 (1978 prices)represented by cumulative investments in construction and equipment, a third of them being in projects under construction(242). The electrical power industry in Brazil is a major industry.

Early History

Pioneering has long been a characteristic of the Brazilian electrical power industry. This was as true in the 1880s, when the industry had its beginning, as in the 1980s, when new ambitious projects are being undertaken. The parallels between the problems encountered in S.E. Brazil a hundred years ago and those in the development of the hydraulic resources of the Amazon region today are extremely close.

Despite its reputation as a developing country, Brazil has often been at the forefront of the world electrical power industry since 1879, when Thomas Edison constructed the first commercial dynamo in New York. In the same year, as a result of the patronage of Emperor

Dom Pedro II, regular illumination was inaugurated at the Estação Central do Rio de Janeiro (central railway station) by the company Estrada de Ferro Central do Brazil, using six arc lamps of the Jablochkov type. This was the start of electricity generation in Brazil using prime movers(243). At the end of the nineteenth century, Brazil was introducing, almost simultaneously, the same electrical services as the more industrially advanced countries of Europe and the USA(244).

In 1881, permanent electrical street lighting was installed in the Praça da Rêpublica, in the city of Rio de Janeiro, using sixteen Jablochkov lamps operated by a steam engine and two dynamos. This was followed two years later by public lighting in the city of Campos, São Paulo state, supplied from a thermal power station, with three dynamos and an output capacity of 52 kW. This remained in operation for eighteen years, with only one cessation of operation, for two nights, in 1901. The first public supply of electricity in Great Britain was in 1881, using hydroelectric power to light the streets of Godalming, but unlike in Campos, the supply was discontinued three years later(245).

Edison patented his incandescent carbon filament lamp in the USA in 1879, and early the following year the first commercial incandescent lamps were demonstrated in London(246). In January 1884, the Bush Swan Electric Light Company of Cleveland, Ohio, USA, demonstrated arc and incandescent lamps in Brazil, and by April the Imperial Palace in Rio de Janeiro was lit by electricity.

In the autumn of 1882, the first hydroelectric station in the USA, at Appleton, Wisconsin started operation. Brazil followed, almost immediately, with a small private hydroelectric power station at Diamantina, Minas Gerais, established on the small river, riberão Inferno, in 1883. The dam created a 5 m head of water, and the power house was equipped with two Gramme generators rated at 8 hp (6 kW) each. These ran at 1 500 rev/min, and were driven by two water wheels of 3.25 m diameter. The power was transmitted a distance of 2 km, by the then longest transmission line in the world, and used in the extraction of gravel. A few months later it was used for illumination(247). Another private hydroelectric power station began operation in Minas Gerais in 1887. Again, the power was used for mineral operations, but this time for ventilation and illumination of the galleries in a gold mine, and for the lighting in employees houses. The installation was owned by the French company Companie des Mines d'Or du Faria, and consisted of two Gramme dynamos operated by a large water wheel with 20 blades, under a head of 40 m, and a maximum mechanical power of 500 hp (370 kW).

The first Brazilian hydroelectric power station to enter into public service was UHE Marmelos-zero at Juiz de Fora, Minas Gerais. The work was pioneered by Bernado Mascarenhas, and was installed on the rio Paraibuna, close to another mark of Brazilian progress at that time, the União-Industria highway. These development initiatives led to the expansion of Juiz de Fora, which became nicknamed "Manchester Brasileira" due to the textile industries which followed the power supply to the town.

The hydroelectric power station consisted of two single-phase alternators, rated at 125 kW each, which operated at a voltage of 1 kV and a frequency of 60 Hz. Seven years later, a second power station, Marmelos-1, was installed at the same site(248). In the

1880s, the capacities of the generators which could be built were so small, that they were used largely to supply the needs of fazendas, which operated cereal mills, saw mills, and other small industries, including textiles fabrication. Little by little, the installed capacities were augmented so as to give greater profitability to the power stations. Industrial autoproducers also began constructing distribution networks and supplying electrical power to the populations in the areas where they were developing their manufacturing activities(249). At this time, various Brazilian cities were installing public electricity supplies. In most cases they were substituting electric lighting for gas lighting, and providing for electrical power and traction. Such supplies of electricity were generally made available by private concerns, both national and foreign, using equipment and materials imported from abroad(250).

By the end of 1892, electricity became more exploited by Brazilian industry with the establishment of small industries close to areas which had falls of water and to centres of production of primary materials. Until that time Brazil had been, almost exclusively, an agricultural country but the advent of electricity gave birth to manufacturing industry, which attracted previously idle wealth. As seen in table III.i, the installed capacity in Brazil increased substantially between 1883 and 1900.

In 1900, the numbers of thermal and hydroelectric power stations installed were similar, but the nominal installed capacity of the thermal stations was about 6.6 MW against 5.5 MW for the hydroelectric power stations. At the turn of the century the flow of resources towards the electrical power industry became more rapid and hydropower began to predominate. The number of companies generating,

Table III.i : Installed Capacity in Brazil, 1883-1900

Year	Installed Capacity MW
1883	0.052
1889	4.618
1890	5.020
1900	12.085

Source : Anon., "A Energia Elétrica no Brasil, 1977, p.55

transmitting and distributing electricity in small locations multiplied rapidly, and with this there came a certain concentration and delimitation of zones of influence, which gave an early definition to the structural development to the power industry in Brazil(251).

Although Brazil was at the forefront of world users of electricity, it did not suffer the same initial problems as were experienced in the USA and Great Britain, where much of the development work was taking place. Many of the men involved in this work were not scientists or engineers, but were business men. They had little theoretical or practical understanding of the subject, but had a strong commercial sense, as in the case of Thomas Edison(252). This is, perhaps, less surprising when it is recognised that there were still some major gaps, and even errors, in the knowledge of the processes involved in the conversion between mechanical and electrical energy.

As the new power and light industry grew, there arose a need for men both technically competent and possessing business acumen. "The first and probably most versatile of the new breed of men in the electrical industry were the arc light salesmen. These men had to be a combination of missionary and promoter because they were selling something - electricity...."(253). Whether or not one agrees with the writer of this statement, it is an undeniable fact that the Brazilians were susceptible to such "salesmen". They did not have the worries of developing the new "product", but they were in the position to make use of what was available. As a result Brazil offered a ready market which the "salesmen" wanted to exploit rapidly, hence the early development of an electrical power industry in Brazil.

"The Era of the Kilowatt"

The construction of power stations at this time required a great pioneering spirit, the work often taking place in isolated locations without adequate access or services. All equipment and much of the materials had to be transported by manpower (possibly slaves) over inhospitable terrain(254). Diseases amongst the workers were common, with malaria, yellow fever and gastro-intestinal diseases rife in the states of São Paulo and Minas Gerais. Despite improved technology and facilities, the isolation and inhospitable climate of the areas being exploited today presents many of the same problems as were faced by the early pioneers.

The technological progress achieved by Brazil, since the beginning of the twentieth century, in the fabrication of large hydroelectric generators, construction of dams and transmission networks must be regarded within the context of the peculiar position of energy reserves within Brazil. Although the absolute magnitude of the hydraulic potential of the country was not known with any accuracy (see p.39), those involved in the energy sector recognised the great possibilities offered by the hydraulic generation of energy as against the use of mineral coal, of which there was no indication of large reserves. These premisses of 80 years ago have remained substantially correct, with little good quality coal having been found but an enormous firm hydraulic potential measured. As a result, most of the early initiatives in the Brazilian electrical power industry were in the use of hydraulic energy.

The use of hydraulic energy required the first electricity companies to establish themselves either in the vicinity of the areas to be developed for power, or in the large consuming centres. In the remainder of the country, including the state capitals, the supply of electricity was sparse, with restricted use or limited supply from small diesel units,and low efficiency gas and wood burning thermal power stations(255).

From 1882, electric lighting slowly began to replace gas lighting in the central streets of Rio de Janeiro, with a more rapid increase from 1884 to 1887. In São Paulo, although electric lighting rapidly increased so did the numbers of gas lights. However, legislation in that city in 1916 authorised electrical illumination of some of the streets, and by 1930 all the gas lights had been replaced by electric lights. In 1887, the same year as electric traction was first introduced in the USA, in Richmond, Virginia(256), the Companhia Ferro do Carril do Jardim Botânico built a 62 kW thermal power station in Rio de Janeiro, to power Brazil's first electric trams.

The company repeatedly tried to expand its services to supply certain establishments with light and power, but this was always countered by remonstrations from the Sociedade Anônima de Gás which also opposed the installation of electric light in the Teatro Lírico in 1894, and won the case in the tribunal. Meanwhile, the Cia. Jardim Botânico was permitted to supply electricity under licence from the S.A. de Gás, to those who requested it.

In 1904 and 1905, the Braconnot enterprise, acting on behalf of S.A. de Gás, erected a small thermal power station in order to supply electric lighting to avenida Central (now avenida Rio Branco) in Rio de Janeiro. This service entrusted to the Braconnot enterprise closed down at the beginning of 1907, when the provisional generator of UHE Fontes, on the riberão das Lages began to be operated directly by S.A. de Gás. Despite operating an electricity generating station, the company still continued increasing the number of gas burners, reaching a maximum of approximately 22 000 in 1909, when substitution by electric lighting was begun in earnest. However, Rio de Janeiro was not entirely illuminated by electricity until 1924.

'The Light'

It was at this time, that companies, financed by foreign capital and under its control, entered into the Brazilian electrical power industry and maintained foreign domination of the industry until the late 1960s. The situation was ideal for this kind of domination. The country had only the beginnings of a national economy, the hydraulic resources were distant (for that era) from the centres of consumption, and there was strong competition from the gas utilities.

Two major electrical energy utilities arose in the two principal consumption centres with the names of São Paulo Light and Rio Light, the only subsidiaries of a Toronto holding company, "Brazilian

Traction, Light and Power"(257). On 9 October 1899, 'The Light' as it is now called, began to operate in the city of São Paulo under the name of "The São Paulo Railway, Light and Power Company Limited"*, assuming the rights and obligations of the concession contract for public service electricity supply. The contract was first signed on 28 September 1899, between the company and the Prefeitura de São Paulo. A similar contract was signed on 20 May 1905, between the company and the then Distrito Federal for the supply of power to Rio de Janeiro, under the name "The Rio de Janeiro Tramways, Light and Power Company Limited". The contract gave the company the right to exercise active control over the S.A. de Gás do Rio de Janeiro which had, until then, held the concession for illumination of the city by gas and electricity.

Various other companies became integrated with these two Canadian owned companies, and they expanded to cover much of the state of São Paulo, and part of the old state of Rio de Janeiro. In a short time a considerable generating capacity and distribution network for electricity supply was installed in the concession areas of these companies(258). The interests of 'The Light' remained extensive, and in 1930 it was claimed that the existence of the public light, power, transportation, gas and telephone services of São Paulo, Rio de Janeiro, Santos and the surrounding regions were directly due to the endeavours of 'The Light'(259). By 1962, almost half the power generated in Brazil was supplied by the two companies. They covered only 0.4% of the area of Brazil and served only 15.2% of

* 'The Light' was established as a Canadian limited company, and retained this status until 1967, when the various companies belonging to the parent company Brascan amalgamated in 1967, when it assumed the Brazilian status of a Sociedade Anonima (see p.161).

the population, yet they were responsible for 46.9% of the energy sales(260).

The company served the major industrial markets of Brazil. The South East region was the centre of the post-war economic boom, which occurred there largely due to the good supplies of electricity enabling industrial expansion(261). The monopoly held by 'The Light' in this region meant that this Canadian company wielded considerable power. American capital in the electrical power industry in Brazil did not become important until the late 1920s when extensive purchases of small companies outside the jurisdiction of 'The Light' gave American ownership to approximately one sixth of Brazil's developed water power(262).

The American Foreign Power Company (AMFORP), a subsidiary of the North American group, Bond and Share Company, began operating in the interior of São Paulo state in 1924. It served the rich coffee producing zone, through the acquisition of various small concessionaires, which latterly had become the Companhia de Força e Luz S.A. (CPFL). At the end of 1927, the company bought control of various other existing concessionaires, and the public services for electricity in most of the state capitals and other cities in Brazil.

AMFORP organised a company called Companhia Auxiliar das Empresas Elêtricas Brasileiras (CAEEB), which supervised and administrated the concessionaires under its active control. These included Companhia Força e Luz Nordeste do Brasil (Natal and Maceiõ), Pernambuco Tramways and Power Company Limited (Recife), Companhia Energia Elêtrica da Bahia (Salvador), Companhia Central Brasileira de Força Elêtrica (Vitoria), Companhia Brasileira de Energia Elêtrica

(CBEE)(Niteroi, São Gonçalo and Petropolis), Companhia Força e Luz de Minas Gerais (Belo Horizonte), CPFL (state of São Paulo), Companhia Força e Luz do Paranã (Curitiba), Companhia de Energia Elétrica Rio Grandense (Porto Alegre), and the Rio Grandense Light and Power Syndicate Limited (Pelotas). As a result, CAEEB operated in all the major state capitals, with the exception of Rio de Janeiro and São Paulo. This gave the company considerable influence in the Brazilian electrical power industry, but it never had the same power as 'The Light'(263).

AMFORP was purchased by the Brazilian Government in 1965. An informal agreement to this effect had been made by the Brazilian and USA Presidents, Goulart and Kennedy in April 1962. This agreement had been made with the objective of improving Brazil's creditability in international lending circles, by the orderly purchase of AMFORP's properties, in order to compensate for the expropriation of AMFORP's subsidiary, Companhia de Energia Elétrica Rio Grandense, by the governor of the state of Rio Grande do Sul, in 1959.

The execution of the Goulart-Kennedy agreement was delayed until 1965, with the result that AMFORP, knowing for three years that it would be leaving Brazil, undermaintained and neglected the replacement of equipment, so as to retain as much of its revenues as possible. The company let its systems run down completely(264). For Brazil, this led to further inadequacies in the electrical power industry.

<u>Hydroelectric Power and 'The Light'</u>

The hydroelectric power station which marked the start of the activities of 'The Light' in Brazil was UHE Parnaíba, on the rio

Tietê, which was constructed between 1899 and 1901. The capacity of the station was 2 MW, exceptionally high for that period, and it supplied the city of São Paulo (population 238 000) with power, not only for illumination, but also for electrically operated transport(265). The original installation consisted of three horizontal water wheels, operating with a head of 75 ft (23 m). The power was transmitted over some 17 miles (27 km) at a voltage of 20 kV. The station was successively expanded until it reached its final capacity of 16 MW in 1912(266).

In September 1912, maintenance of a reliable supply of electricity became increasingly difficult as a drier hydrological cycle was entered, which caused a succession of low flows in the rio Tietê. This led to an increased search for new hydraulic sites, but the thermal power station, UTE Paula Souza, was inaugurated at the same time (with two 2.5 MW generators), so as to relieve the emergency. The idea of constructing another hydroelectric power station, UHE Pau D'Alho, 39 km downstream of UHE Parnaîba was abandoned, and, in 1914, the first two generating units of 'The Light's' UHE Itupiraranga, on the rio Sorocaba, came into operation with a capacity of 18.4 MW(267,268). Shortly afterwards, the third unit began operation, bringing the total capacity of UHE Itupiraranga to 22.2 MW(269). This led to a period of of relative stability within the São Paulo electrical system. The energy produced was transmitted to São Paulo at a voltage of 88 kV (high for the era) in order to maintain electricity supplies to the industrial South East, which was rapidly expanding as a result of the importation difficulties arising due to the First World War. With the purchase of the land needed to build UHE Itupiraranga, the company acquired the Empresa de Sorocaba and the Banco União de São Paulo, which increased its control in the electrical power industry.

'The Light' won a contract to supply power to the Companhia Paulista de Estrada de Ferro in order to electrify the railway track from Jundiaí to Campinas. This, coupled with an overall increase in demand, necessitated further expansion of UHE Itupiraranga and in June 1925, a fourth stage was completed, adding an extra 22.8 MW(270)*. The timing was inopportune for increasing the capacity of this station, as the area had been suffering a severe drought for more than a year, and the reservoir had been almost emptied(272). Measures had been taken to overcome the problem and two further generating units, totalling 5 MW, were added to UTE Paula Souza. However, the accelerating requirements for electricity meant that this thermal station already could not cope with the demand.

The 1924 drought was the cause of the first major energy supply crisis experienced in Brazil. In the first eight months of that year, measurements from 52 meteorological stations showed that rainfall was only 58% of normal. Despite this, another new hydroelectric power station, UHE Rasgão, was built downstream on the rio Tietê. Two 9.3 MW units entered into operation, two months apart, in 1925 only eleven months after the first proposal of construction(273). This action, of constructing a hydroelectric power station in the same hydrological area, was not going to solve the problems of supply, especially in dry years, to the fast growing demand of industrial São Paulo. It was necessary, therefore, to look to alternatives to ensure

* This figure was put at 16.4 MW by another reference source(271), but the other figure has been adopted as more likely. There is no obvious reason for the disparity.

a cheap and abundant supply of electricity for the 730 000 inhabitants of the city, which had increased three-fold in size in 25 years(274).

During the previous 25 years, supply in the two major cities had managed to keep up with demand, with very little increase in capacity. 'The Light' had only installed one extra hydroelectric power station between 1914 (UHE Itupiraranga) and 1925 (UHE Rasgão), and that was UHE Ilha dos Pombos (1924) to supply the city of Rio de Janeiro. The Companhia Paulista de Força e Luz (CPFL) had installed a small station, UHE Jaguarí, in São Paulo state in 1917(275), but it was not until the burgeoning demand of São Paulo city began to dictate the market did further exploitation of hydroelectric sources take place.

The Great Project : The Serra do Mar

The first of the large modern power stations to be built in Brazil was UHE Cubatão (UHE Henry Borden), otherwise known as the Serra do Mar development. "The Light" had taken advantage of the hydraulic potential of the head waters of the rio Tietê, near São Paulo city, and the rio Paraíba and its tributaries, near Rio de Janeiro, in order to supply these two cities with electricity, but the most important source of hydraulic power, for both cities, was to come from the Serra do Mar development(276). Long before the construction of UHE Itupiraranga (1914), 'The Light' had begun studies of possible energy developments in order to be able to maintain supply to the city of São Paulo. It had assessed the economic value of the hydraulic resources located close to the centre of consumption and, in 1911, it had acquired land in the rio

Itapanhaú basin, on the oceanic slope, with an outflow into the canal of Bertioga. In 1913, it also purchased the falls of the rio Juquia. The first of these acquisitions was the initial step towards the beneficial energy exploitation of the Serra do Mar(277).

The Serra do Mar is the edge of the great central plateau of Brazil. This plateau slopes gently inland towards the centre of the country and most of the rivers, with their headwaters in the Serra, flow inland into the basins of the rios Paraná and Paraguaí, and, finally, reach the sea at the rio de la Plata. A small number of rivers flow down the coastal escarpment, formed by the Serra and directly into the Atlantic Ocean(278). On the sea facing slope of the escarpment the rainfall is one of the highest in Brazil, over 2 000 mm per year(279). In the 1930s, accurate records were not kept for the region of the Serra do Mar which was to be exploited, but estimates ranged from an average of 5 000 mm per year(280) to a recorded maximum of 6 800 mm in 1929(281). Such a high rainfall made development in this region extremely difficult and ambitious.

The plans of 'The Light' were to reverse the flow of some of the inland flowing rivers, at their head waters, and, by means of a complex system of dams, canals and pumping stations, use the head created for hydroelectric power generation at the base of the scarp(282).

The original plan was to exploit the favourable conditions at the edge of the plateau, overlooking the Baixada Santista, by diverting the head waters of the rio Tietê and using the head of 640 m at Itapanhaú. The engineer originally in charge of the project, Walter Charnley, also intended to make use of the waters from the rio Paraibuna, a tributary of the rio Paraîba, by damming it upstream of Bairro Alto. The retained waters were to be diverted to the coast to a power station of 136 MW capacity, situated at the foot of the Serra in the valley of the rio Mococá. The studies of the Itapanhaû scheme had reached an advanced stage, when the project for the expansion of electricity generation to supply the city of São Paulo was entrusted to the Canadian Vice President of 'The Light', Asa White Kenney Billings, who was renowned in the field of construction of hydroelectric power stations in Spain, Mexico and Brazil(283).

Billings examined the difficulties which, in his opinion, the construction of UHE Itapanhaû would present, especially the transportation of heavy equipment and the geological conditions to be found on the site of the proposed powerhouse. He decided to employ an engineer, F.S. Hyde, to collect new data for the project, and to study alternative schemes along the escarpments of the Serra do Mar. Hyde pursued his studies under difficulties; accurate maps were not available, a condition existing today in the Amazon Basin (see p.240), infrastructure was lacking, as was knowledge of hydrological, climatic and geological data. After exhaustive research, he recommended damming the rio Grande, one of the tributaries of the rio Tiete, diverting the waters towards the rio Pedras and thus forming a reservoir. This plan was adopted in preference to the Itapanhaû scheme, because of its greater available head, greater storage volume, better local infrastructure and closer proximity to the market.

Billings had become fascinated by the concept of diverting the courses of the plateau rivers over the escarpment, and believed that such an "obvious" scheme should have been devised long before :

> "At any time during twenty years this plan could have been easily determined from the topographic maps of this region of which thousands of copies were sold to the public. Anyone capable of tracing the contours on these maps can imagine the whole plan. Yet no-one did this and three independent investigations passed by the region as devoid of interest, even though it was on the principal highway and included the only cascade on the Serra which is visible from the sea port. This seems a somewhat remarkable fact"(284).

However, Billings has also been reported as saying

> "... a dam 90 feet (27.7 m) high on the Tietê river a few miles below the city of São Paulo would back up this river, flooding a large part of the city as the water rose to form a lake of 106 square miles (275 km^2) in area and of 2 000 000 acre-feet (2.45×10^9 m^3) in volume at an elevation of 2 408 feet (734 m) above sea level. When this elevation was reached,the impounded waters would commence to flow in the other direction to the ocean over the lowest depression in the almost imperceptible divide near the edge of the plateau. This flow could thus be made use of in the drop of 2 380 feet (726 m) to the coast plain. It would be impracticable, however, to build such a lake, for it would flood most of the city and destroy the market for power"(285).

This is an amazing conclusion for the man who was responsible for some of the major early hydroelectric projects in Brazil. Even at that time, the 1930s, it was obvious that the companies concerned were only interested in selling electricity and not in providing a public service. To quote, as the principal reason for non-construction of a project, the loss of the market, as opposed to the loss of homes, agricultural land and livelihood is rather insensitive.

The first step in the Serra do Mar project was authorised by Federal decree in March 1925, and by state law in December. In its original form it comprised a main reservoir on the rio Grande, a tributary of the rio Tietê, supplemented by twelve smaller reservoirs to be built successively as needed. The surplus flow from each, after discharge of the "normal dry season flow", would be diverted by canals and tunnels to the powerhouse at the foot of the Serra. During the initial construction period, further study indicated that the reservoir level should be raised a further 22 feet (6.7 m), increasing the reservoir area from 26 sq.miles (67 km^2) to 44 sq.miles (113 km^2), and the storage volume from 311 000 acre-feet ($0.4 x 10^9$ m^3) to 835 0000 acre-feet ($1.1 x 10^9$ m^3). Studies also suggested that all the proposed canals and tunnels be replaced by a single canal to conduct the surplus from the reservoirs, as well as the flood waters from the rio Tietê which would be pumped to the main reservoir(286).

The first commercial operation of UHE Cubatão began in October 1926, only one year after official authorisation of the project(287). However, the preliminary surveys undertaken before the start of construction required many months of work which was hampered greatly by the dense undergrowth. Pathways had to be carved through the packed vegetation to the extent that for the topographic survey of the major reservoir area over 4 000 km of trail had to be cut(288). This problem is very similar to that being experienced today in the Amazon basin, where men with chain saws are lowered into the forest from helicopters in order to prepare clearings and landing strips before survey work can begin.

The most serious problem faced at UHE Cubatão was, in the event, malaria. In the 1920s it was still highly endemic in São Paulo state (as it still is in the Amazon basin) and presented a serious threat to the success of such an ambitious enterprise. At that time malaria was endemic on the coastal plain, and in a large part of the interior. However, it was absent in the region along the west of the Serra(289). The disease had already been responsible for the failure of a number of Government projects in the area(290), but it had not been found on the scale which caused the disaster in the building of the Panama Canal, where thousands died(291). As a precaution, 'The Light' employed an eminent health expert, Arthur Neira, to lead the fight against the disease. He was aware of what had happened in Panama, and disagreed strongly with the company's decision to place the 4 000 workers in night time camps at the foot of the Serra, where the incidence of mosquitos was high. Disaster was averted as a result of the constant vigilance of his team of doctors who were put into position of command by the company(292).

At the time it was believed that the best way to fight the malaria was to prevent the introduction of carriers onto the work site. Every labourer was examined on recruitment and again before commencing work, to check for evidence of the disease, which was usually the benign tertian type mixed with some malignant tertian. Those men with an enlarged spleen, or other evidence of malarial infection were rejected(293). No prophylactics such as quinine were administered, no mosquito screening was used on buildings, but all open water was regularly inspected for mosquito larvae. Anyone who reported sick was sent to the doctors who would do a blood test if malaria was suspected. If it was diagnosed, the patient was sent to hospital for at least thirty days or until no trace of parasites could be found in the blood(294).

UHE Cubatão

Over the period 1925 to 1935, eight dams and two reservoirs were constructed for this scheme. The two reservoirs were Billings, on the rio Grande, and Pedras at the crest of the Serra. The storage volumes were, respectively, 1 230x10^6 m^3 and 49x10^6 m^3, and they were connected by the Summit Canal, which was 16 km long. Only two of the dams had spillways, the Summit dam on the Billings reservoir, spilling to the Pedras reservoir and the Pedras dam on the Pedras reservoir(295). This ambitious scheme was modified during construction, and the addition of pumping stations allowed water to be transferred between reservoirs and abstracted from the rio Tietê, thus enabling the scheme to serve the dual purpose of generating power and alleviating the floods in São Paulo.

Billings estimated that each square mile (2.6 km^2) of drainage area on the Serra do Mar provided from 600 hp to 2 500 hp (170 $kWkm^{-2}$ to 720 $kWkm^{-2}$), averaging 1 000 hp (300 $kWkm^{-2}$) at a 60% load factor. He believed that the Serra do Mar development should not be considered as a single installation but as a "flexible programme of many steps to be carried out when needed", which would be able to accommodate the growth of load for the next 20 or 30 years(296). Although this predicted additional potential has not been used, the only completed Serra developments are UHE Cubatão and UHE Lages (built in 1924), the project was indeed flexible. Much of the work on UHE Cubatão, in the 1920s, was innovative, especially with respect to the penstocks. The first two, completed in 1926, were designed along conventional lines. A third was modified to give greater strength and a lower unit cost, but, despite the good performance, the engineers were convinced that the basis of conventional designs was far from optimum, and an intensive study was therefore carried out, in mid-project(297).

Not only was the structure of the penstocks reviewed, but the problem of internal protection was studied. Bituminous enamels were used in order to reduce the periods when the penstocks were out of service for maintenance, but the enamels had to be able to withstand the temperatures of 73 °C which were reached when the penstocks stood empty in the sun. Whitewashing the outside could reduce the temperature by 16 °C but was insufficiently durable. Consequently, aluminium paint in spar varnish was used, although it only reduced the maximum temperature by 7 °C(298).

The limited materials available in the 1920s, coupled with the novelty of the problems, were common features of all the hydroelectric developments of the period, and the pioneering spirit then evident manifests itself today in the similar problems arising in the Amazonian hydroelectric developments. The comment made by Billings in his 1936 lecture to the Institution of Civil Engineers was valid then, and still is today, and it epitomises the continuing innovative nature of hydroelectric power developments.

> "It may be noted that hydroelectric work differs from other construction in that practically the entire design depends on local conditions, with the result that hardly any two plants are alike".

Due to the variations in geology, climate and streamflow, knowledge of which are fundamental to a hydroelectric scheme, detailed and long term observations of relevant parameters must be made. In Brazil, rainfall, evaporation and other hydrological factors are so variable that streamflow cannot be estimated from run-off expressed as a percentage of rainfall; it is always necessary to guage the actual streamflow. When UHE Cubatão was built Government records were scanty or non-existent, and it was necessary for 'The Light' to maintain its own corps of observers, to obtain the necessary data(299).

Despite all the problems encountered as a result of the innovative nature of the scheme, the first generator of UHE Cubatão started commercial operation in 1926, with a capacity of 44.4 MW, and thus the climax of the evolutionary process which had begun in the last year of the nineteenth century was reached. This pioneering of hydroelectric power unleashed a process of intense interaction, in Brazil, between energy and progress. The consequent increase and diversification of the uses of electrical energy in São Paulo required the almost uninterrupted expansion of the installations on the rio Parnaîba, until the limiting capacity of the Guarapiranga reservoir was reached. The first unit at UHE Cubatão established itself as the focus of the subsequent works, which incorporated the abundant waters of the rio Tietê and utilized the rio Pinheiros, which flowed through a valley unsuitable for human habitation because of high rainfall and endemic disease.

It also transformed the Serra do Mar from being a barrier to the economic growth of the country into one of the key factors in Brazil's development(300). The fact that 'The Light' managed to design and execute this project in such a hostile region with almost no transport system, between the coast and the city of São Paulo, gave the company the reputation of being a major contributor to the development of the South East region of Brazil(301).

After the installation of the first operating unit at UHE Cubatão further generators were installed sequentially until the final one, the eighth, came into operation in June 1956. The final capacity of the station was 474 MW(302). When further extension to the powerhouse became impossible, a second powerhouse, UHE Henry Borden, with six generators, was installed in a large subterranean cavern excavated close to UHE Cubatão. When complete, in December 1961, this raised the overall capacity of the system to 914 MW. Like UHE Cubatão, UHE Henry Borden was viewed as a development milestone. Its entry into service with its first unit in 1955, coincided with the period during which President Jucelino Kubitschek was defining the Federal Government philosophy on development. This gave priority to the economic expansion which was being experienced by the industrial South East at that time(303).

UHE Fontes

Not only was 'The Light' responsible for UHE Cubatão, and the major supply of electricity to São Paulo, the company also played a similar role for the city of Rio de Janeiro with UHE Fontes. This work began much earlier, in the first decade of the twentieth century. It was intended to clean up the then rather insalubrious city and make it more attractive and modern. The terms of the accord, signed between Rio de Janeiro Tramway, Light and Power Company Limited and the government of the then Federal District, gave the company the right to exploit industrially the Cachoeira de Riberão das Lages (the falls of the small river Lages). Work began in 1905, and in 1907 a temporary powerhouse was completed in order to help meet the most urgent needs of the city of Rio de Janeiro. In March 1908, UHE Fontes was inaugurated, with six generators giving a total nominal capacity of 24 MW, with an overload rating of 36 MW. The power was transmitted over the unusually long distance, for 1908, of 81 km, at a voltage of 44 kV. The reservoir, with usable storage of 182×10^6 m^3, equivalent to 112 GWh, was formed by closing the riberão das Lages by a 32 m high concrete arch spillway dam (one of the highest in the world at that time).

The economic development of Rio de Janeiro during this period was due, in large part, to the availability of energy from UHE Fontes and, after only five years, it was necessary to augment the generating capacity of the station. This was effected, in 1914, by the first river diversion in Brazil in which the headwaters of the Piraí, dammed by the Tocos dam, were diverted by gravity flow, through an 8.5 km long tunnel to the Lages reservoir. The diverted water supplied two additional generators, and the capacity of the station was raised to a maximum rating of 64 MW, and the transmission voltage was raised to 88 kV. For 15 years UHE Fontes served as the sole major electric power station supplying the Federal District of Rio de Janeiro and its outlying towns, but in order to cope with population increase and the extension of use of electricity, another station, UHE Ilha dos Pombos was constructed on the rio Paraíba.

Once again, the engineer in charge was A.W.K. Billings who, in 27 years in Brazil, was responsible for an increase in Brazilian installed capacity of 800 MW. UHE Ilha dos Pombos was a run-of-the-river scheme, with five generating units and a total capacity of 167 MW. In conjunction with UHE Fontes it met the needs of the Federal capital until the start of the Second World War. The onset of war in Europe, however, led to difficulties in the importation of manufactured goods into Brazil and to an immediate need for import substitution. This led to an expansion of industry and the need for increased power generation. It was proposed, therefore, to raise the height of the Lages dam by 28 m, and so increase the available storage in the reservoir to 1 050x10^6 m^3 (780 GWh). Such increase in height has rarely been undertaken and it involved very careful planning and close attention to technical details(304-306). However, the successful increase in hydraulic reserves allowed the expansion of UHE Fontes by 190 MW.

The final development in the system of 'Rio Light' was begun in 1948, with the Paraība-Piraī diversion to the Lages reservoir. This was completed in 1952, and it supplied the sub-terranean power station of UHE Nilo Peçanha, with an installed capacity of 6x60 MW, and the enlarged UHE Fontes. Another hydroelectric power station was built 4 km downstream to use the discharged water from these two power stations. The 100 MW UHE Pereira Passos (Ponte Coberta) was inaugurated in 1962. This was the last power station to be constructed by 'The Light'. Thereafter, the company confined itself to distribution.

This change in the role of Rio Light coincided with the reorganization, on a national basis, of the whole electrical power industry in Brazil (see p.160). In fact, at the time of the Lages diversion project, a transmission line from UHE Cubatão to UHE Fontes came into operation and unified the system of 'The Light', despite the frequency difference between the two systems (see p.133). This was effected by converting the 50 Hz to 60 Hz at the 50 MW Aparecida frequency conversion station. This transmission line, 330 km long, operating at 230 kV, was for many years the longest in South America. The 'Rio Light' and 'São Paulo' systems finally amalgamated to form the LIGHT - Serviços de Electricidade S.A. ('The Light') in 1967, with a total installed capacity of 1 950 MW(307).

The expansion of the Lages system signalled the end of the era of hydroelectric power developments close to the consumer markets of the main industrial centres. Although future schemes were designed to meet industrial energy needs, planning changed from city oriented to river basin oriented. All new developments were to be geared to the best use in energy terms, of the available water resources. Between 1948 and the early 1960s only two major hydroelectric power generation schemes were completed, although many smaller stations were built, often by private companies for their own supply. These two large schemes were UHE Paulo Afonso, on the rio São Francisco in Bahia, which began operation in 1955, and UHE Três Marias, on the southern end of the same river, in the state of Minas Gerais. This began to generate in 1960(308).

The rio São Francisco is the longest river wholly contained within Brazil. It rises in the heart of Minas Gerais, flows northwards and then eastwards, along the border between Pernambuco and Bahia, and then the border between Alagoas and Sergipe, for a total of 3 160 km before flowing into the Atlantic Ocean. There are no major ports on this river because of its general lack of navigability, but it supports three important hydroelectric power stations, UHE Paulo Afonso, UHE Três Marias and UHE Sobradinho. In its course it crosses some of the most poverty stricken areas of Brazil, where the climate is harsh and subject to prolonged droughts.

Initial studies of the river were made, by Henrique Guilherme Hanfield, in the middle of the nineteenth century, under the patronage of Emperor Dom Pedro II. However, the first serious consideration of the hydroelectric potential was not made until the Companhia Hidrelētrica do São Francisco (CHESF) was created in 1945 in order to build and operate UHE Paulo Afonso.

UHE Paulo Afonso

This hydroelectric power station was built at the site of what used to be a natural waterfall with four cascades with a total height of 82 m. On seeing the falls the explorer Richard Burton has been quoted as saying "Power tremendous, inexorable, irresistible"(309), but the power station has largely destroyed them. The first hydroelectric power station at Paulo Afonso was inaugurated on 26 January 1913, with a power rating of 1 600 hp (1 200 kW), in order to supply a small textile factory, but with the creation of CHESF the development of the Paulo Afonso site as a major electricity source began in February 1949.

The works which were commenced at that time marked the first entrance of the Brazilians into the complex domain of water resources planning for electrical power(310). Much of the engineering was innovative, but the project was successfully implemented(311). UHE Paulo Afonso symbolised the beginning of a Governmental presence in the electrical power industry and it gave a new dimension to the success of large mixed economy enterprises. For the first time it was possible to establish factories capable of manufacturing heavy electrical and mechanical equipment and begin the process of import substitution in this important sector of the economy.

On 1 December 1954, the dam was closed. The powerhouse was the first sub-terranean one in Brazil, and it commenced operation with two 60 MW generating units. This was, however, only the first phase of the overall plan. It was followed by UHE Paulo Afonso II, which also had a subterranean powerhouse and a capacity of 180 MW, and UHE Paulo Afonso III which entered into service in 1974 with 2x216 MW generators. Work immediately began on UHE Paulo Afonso IV which, in its first stage, is planned to have 5x375 MW generators. The planned final installed capacity is 2 250 MW. Integral with the Paulo Afonso system is UHE Moxotó, built on a tributary of the rio São Francisco, This entered into service in 1977 with 4x110 MW generators. The transmission line from UHE Paulo Afonso to the Centro Industrial do Recôncavo Baiano was the first 500 kV line in Brazil(312).

UHE Furnas

UHE Furnas, and the FURNAS company, which was created to build the power station, both signify a turning point in the Brazilian electrical power industry. During 1956 the Conselho de Desenvolvimento (Development Council) which was responsible for national economic planning, pointed out, to the Federal Government, Brazil's increasing energy needs. With the pioneering experience of UHE Paulo Afonso behind them, it was decided that the sensible economic step to be taken would be to concentrate resources on a large project, with the collaboration of the state governments of São Paulo and Minas Gerais, and the companies of 'São Paulo Light' and CPFL. The project was to be the construction of a 1.2 GW hydroelectric power station at the Furnas site on the rio Grande(313). The site had been discovered a few years earlier by CEMIG, but the size of the proposed project was considered too large for the CEMIG market alone. Therefore, the Federally sponsored company, Central Elétrica de Furnas S.A. (later to become Centrais

Elétricas de Furnas S.A., (FURNAS)) was established in 1957 in order to develop the hydroelectric potential of the Furnas site(314).

The Federal Government regarded FURNAS as a means of entering the field of electricity production in the South East region, which had been, until then, dominated by state and private enterprises. It wanted to try to overcome the crisis of electricity supply which was beginning to cripple the economic and industrial centre of Brazil. Existing power stations, and those under construction or planned by the private and state companies, were, for a variety of reasons, not able to meet the future needs of regional development. The electrical power industry in the region was stagnating(315). It had become increasingly urgent to install a further 1 000 MW of capacity, a move which was ambitious when it is considered that the total installed capacity at the time was only 3 000 MW.

The World Bank granted a loan to finance the foreign exchange costs of the project (see p.66), and FURNAS was established, with three ex-directors from CEMIG in key positions. At the time of its inception, the company was proud of being the only authentic "mixed state"* enterprise in Brazil, a concept which is still important to Brazilians today (see p.140). Two private shareholders held 60% of the preference stock, but the percentage held by the majority shareholder, 'São Paulo Light' soon dropped to 1 or 2% as the Government assumed greater control(316). When FURNAS was created, the major shareholders were the Federal Government, the state governments of São Paulo and Minas Gerais, São Paulo Light and CPFL. However, the Federal Government, in the guise of the newly formed ELETROBRAS (see

* mixed state or mixed economy enterprises in Brazil are those with capital backing from both government and private sources.

p.153), soon came to hold the majority of shares and Government participation is now greater than 95%. Before the start of the Furnas project, the Federal Government had little influence in the electrical power industry of the South East, but even before installation of the UHE Furnas generating units was complete, the role of the Government in the region had been established(317)

Despite financial problems resulting from high rates of inflation, the Furnas scheme was considered a development success. In energy terms it was viewed as a dynamic component of Brazil's fast escalating economic development, and as a mark of technical achievement. It also led the way for the rapid development of the cascade scheme on the rio Grande(318). At the inauguration of the first stage of UHE Furnas on 12 May 1965, the president, Castelo Branco, simultaneously detonated a charge of dynamite and initiated the works for UHE Estreito. His words at the time mirrored the Brazilian view of the whole scheme.

> "...these are two eloquent and symbolic events, which express the country's determination to progress"*(319).

UHE Furnas not only met the immediate needs for additional generating capacity, but it also established a basis for meeting future demand in the South East region. It was instrumental in the interconnection of the three large consumption centres of Rio de Janeiro, São Paulo and Belo Horizonte, which form the vertices of the economic triangle of Brazil. Initially, Rio de Janeiro was excluded from the scheme because of its different operating frequency of 60 Hz, but it indirectly received power from the scheme through the frequency

* "...ha nos dois acontecimentos eloquente simbolismo, expressiva imagem de continuidade nacional que, de modo categõrico, afirma invencível determinação de progredir".

converter at Aparecida operated by 'The Light'.

The rio Grande rises in southern Minas Gerais and flows west for 1 200 km before joining the rio Paranaība to form the rio Paranã. The Furnas site lies in Minas Gerais. The main dam is a rockfill structure, and the reservoir has backed up two rivers to inundate a total area of 145 950 ha.The regulating effect of this reservoir was seen as a key factor in the development of a further potential of 7 GW on the rio Grande. The total installed capacity of UHE Furnas is 1.2 GW. Despite difficulties in maintaining the schedule, the first generating unit began operation in September 1963, and the remainder followed as scheduled, to supply the region through more than 1 000 km of 345 kV transmission line(320,321).

The first station of this cascade system was UHE Peixoto, which began operation in 1956 under the name of UHE Mascarenhas de Moraes, with a capacity of 477 MW. The cascade system now comprises five hydroelectric power stations, with a combined installed capacity of 4.5 GW, which supply, in conjunction with three thermal power stations and one other small hydroelectric power station, a total area of 1.5×10^6 km^2(322).

The technical success of UHE Furnas was probably due to the hard line taken by the FURNAS directors, especially its president John Cotrim (now chief engineer with Itaipu Binacional) (323). From the outset, the company never accepted the philosophy of co-operation with, or aid to Brazilian industry. Its stated objectives were low cost and reliability. The civil works and the engineering were all foreign, and 87% were paid for in hard currency. Nearly all the equipment was imported because, despite pressure exerted on the

Table III.ii : Energy Production by the Furnas Cascade

Power Station	Installed Capacity * MW	Energy Production # GWh
Marimbondo	1 440	7 895
Furnas	1 216	5 991
Estreito	1 050	4 458
Peixoto	476	3 162
Porto Colômbia	320	2 181

Source : * Public Relations Document, FURNAS 1977

FURNAS Annual Report, 1978

company to buy Brazilian, Cotrim did not consider that the industry could meet the required deadlines or produce adequate reliable equipment. However, FURNAS endeavoured to be fair with the engineering companies, and if one proved reliable for small scale contracts, sizable ones would be awarded later. In fact with the latest FURNAS works, at UHE Itumbiara, all the engineers are Brazilian, as is 80% of the equipment(324). (It should be remembered that the current Federal Government is very strict with operation of its "Brazilianisation" policies). UHE Furnas was completed on time, and since then has operated without serious problem.

In the beginning, FURNAS had control of the largest hydroelectric power stations and largest reservoirs in Brazil, and, as it also had control of the regional water storage reservoirs and the interconnecting systems, it could guarantee the operation of the hydraulically interconnected plants. With such an interconnected system, controlled use of water in reservoirs and thermal power to complement the hydroelectric system, FURNAS was able to optimise the system, and it became the pioneer for computer optimization of power systems in Brazil. However, in 1973-1974 ELETROBRAS put into operation the Grupo Coordenador de Operação Interligada (GCOI) (see p.173) and FURNAS lost its strategic planning position(325).

UHE Furnas signified the start of a planned approach to river basin development. Previously, most hydroelectric sites had been developed individually with little thought being given to integrated schemes. However, in recent years, this process has been changed, especially since most of the prime sites close to the industrial markets have been utilized. The principal examples of this co-ordinated river basin planning are the cascade system on the rios Tocantins-Araguaia (see appendix 4) and that on the wholly Brazilian stretch of the rio Uruguai (see page 106).

<u>UHE Três Marias</u>

At its inception, the hydroelectric power station, UHE Três Marias, was regarded as the key project for a major power and reclamation development in Brazil. It was part of a joint undertaking by the Comissão do Vale do São Francisco (CVSF) and CEMIG. It was conceived during the era when other bold projects were in progress, including the construction of the new capital Brasilia, and the Belém-Brasilia highway through the Amazon jungle.

The scheme was part of a large reclamation programme in the rio São Francisco valley, which had the aim of raising the economic standards in the valley. The CVSF was given authority to operate by the Brazilian Congress in September 1946, and its first large undertaking and principal project was UHE Três Marias. All the hydraulic structures, such as the dam, intakes and penstocks connected with river-flow control were financed by CVSF, and all power facilities, including transmission lines, were financed by CEMIG, who was responsible for the supervision of design and construction of all the works.

It was necessary to control the river discharges to improve navigation of the river, and to prevent periodic flooding. This was done by means of the Três Marias dam. This is a 2 700 m long earthfill structure 70 m high. Use of concrete was kept to a minimum because of its high cost, and every effort was made to maximise the use of local materials. The power output of the hydroelectric power station is not high, the total installed capacity being 520 MW. However, when initial construction began, in 1956, it was one of the larger power stations in Brazil.

As the project was established in an isolated location, it was necessary to construct housing for the workers and access roads, however, the construction problems for this project were not as great as for other projects in Brazil. UHE Três Marias is significant in being the first major power station integrated with general water resources development in Brazil(326,327).

<u>The Uruguaî Basin</u>

The Uruguaî Basin was first studied in 1968, by CANAMBRA (see p.184), when it was regarded as less attractive for power development than the rio Iguaçu, because of its uneven hydrological cycle of dry periods alternating with extremely high flows. The development of the river revolved around the possibility of having an integrated scheme, either with or without the diversion of the headwaters of the rio Canoas to the Atlantic Ocean. CANAMBRA selected as the most promising project in the basin, the rio Canoas diversion, although it appeared that it might have an adverse effect on any other downstream developments. It also recommended further study of the Pinheiro scheme(328). In the event, no power development of the rio Uruguaī was undertaken, because, at that time, there was little industrial demand for electricity in the states of Rio Grande do Sul and Santa Catarina.

In 1977, a second water power survey of the rio Uruguaī basin was carried out by Centrais Elētricas do Sul do Brasil S.A. (ELETROSUL) (see p.158) and the Consorcio Nacional de Engenheiros Consultores S.A. (CNEC). These studies were aimed at selecting the best overall scheme for the development of the river basin for power, and, at the same time, defining the technical and economic parameters of the various power stations which would be components of the selected scheme. The financial resources for this study were supplied jointly by ELETROBRAS, the Financiadora de Estudos e Projetos (FINEP) and the Banco Regional de Desenvolvimento do Extremo Sul (BRDE)(329).

Increasing world petroleum costs, and the consequent escalation in the cost of oil-fired generation of electricity, have made previously unattractive hydroelectric schemes competitive. With the progressive expansion of electrical power generation in the South region, including such large scale projects as UHE Itaipu, UHE Salto Osorio, UHE Salto Santiago and UHE Foz do Areia, the advantages of electrical connection between the two regions has become significant (see p.138). The increased utilization of the hydraulic resources of this region, by the development of the rio Uruguaī, has become increasingly important for the industrial South East.

One of the objectives of the most recent study was to select the best alternative for promoting optimum use of the available hydraulic resources at a competitive cost, following proper consideration of the technical aspects and the socio-economic implications(330). For many years, the criteria for the choice of construction of a particular hydroelectric power station in Brazil have been to satisfy a particular demand or economic restrictions. However, it is now becoming increasingly common to consider social and environmental factors as well(331).

The ELETROSUL-CNEC report recommended that the hydroelectric power stations UHE Machadino and UHE Itã be constructed, one for the reason of size and the other for the reason of the low unit cost of energy (around US$ 15/MWh, January 1979 prices). It was also recommended that work on UHE Machadino be started immediately. There was a strong reaction from the local people to this suggestion. On 24 March 1980, some 250 farmers, representing the towns in the region of the upper rio Uruguaī basin, met in the town of Concordia in order to discuss the problems which would occur as a result of the construction of the dams(332). This was not the first incidence of opposition to a power project, as demonstrations had previously been held in the North East of Brazil(333), but it may possibly be the first occasion on which it may be successful.

The total scheme for the rio Uruguaī involves the construction of up to 20 hydroelectric power stations by the year 2000, but the farmers immediate concern was with the two stations now being built. Already, there has been damage to land and crops as a result of survey work. In some cases compensation has been offered but not paid. The farmers have not been told any facts about the situation, which is a difficult obstacle to overcome, as accurate details are not yet available. The decision to undertake the projects was undertaken at the preparatory survey stage, and further studies will have to be made before the projects are finalised. However, if all the twenty schemes are built, a considerable area of agricultural land will be inundated, and compensation to the farmers is a subject which will be avoided as long as is possible by the indemnifiers. The farmers believe that there will be little benefit for them from the increased generation of electricity, and they resent the fact that it will be the poor and small scale farmers who will suffer the greatest losses, not the large estate owners(334).

The possibilities of multiple use of the river, such as navigation, irrigation and flood control were studied, but no specific recommendations were made, which in the words of ELETROSUL and CNEC, "... invests a superficial character in these analyses". The only use of the river considered important by the Brazilian Authorities is its harnessing for power(335).

The development of the upper reaches of the rio Uruguaī are of direct concern to Argentina and Uruguay. After the confluence of the river with the rio Peperi-Guaçu it flows southwards, forming the international frontier between Brazil and Argentina. South of its confluence with the rio Quaraī it forms the international frontier between Argentina and Uruguay. Any hydroelectric developments by Brazil on the upper reaches could have a considerable effect on any binational projects downstream. A Brazilian-Argentinian treaty on the hydroelectric development of their jointly owned stretch of river makes no specific reference to any projects, but it establishes the judicial and political bases on which projects may be executed.

Through the treaty Brazil is committed to guarantee that any construction undertaken does not prejudice any existing installations on the river, including the joint Argentinian-Uruguayan scheme UHE Salto Grande. Relationships are already strained between Brazil and Argemtina over the Itaipu and Corpus schemes (see p.118), and the speed with which Brazil has decided to go ahead with the UHE Machadino and UHE Itã projects, with no feasibility studies having been made, is going to cause great concern in Argentina.

UHE Itaipu

UHE Itaipu is the largest hydroelectric power station in the world currently under construction. It is a giant binational project, on the rio Paranã, jointly owned by Brazil and Paraguay. To quote from one of its public relations documents :

> "The Indian word Itaipu means the "singing stone". Because it represents the cultural background of both countries, its meaning shall forever be contained in its new significant dimension - Itaipu, the largest hydroelectric power station in the world"(336).

This sentence suggests a unity which does not exist. Paraguay, Brazil's partner in the undertaking, has suffered considerable financial losses(337), and there has been little harmony with the downstream neighbour, Argentina(338). The significance of the project, however, lies in the technological and organizational achievement in its construction, and in the fact that its existence has unified the electrical power industry in Brazil (see p.116).

Much has been written about this great project, most of it repetitive, and very little of it new. It is the project displaying the new Brazil to the world. Groups of tourists are readily shown an expert and eloquent slide show, followed by an informed tour around

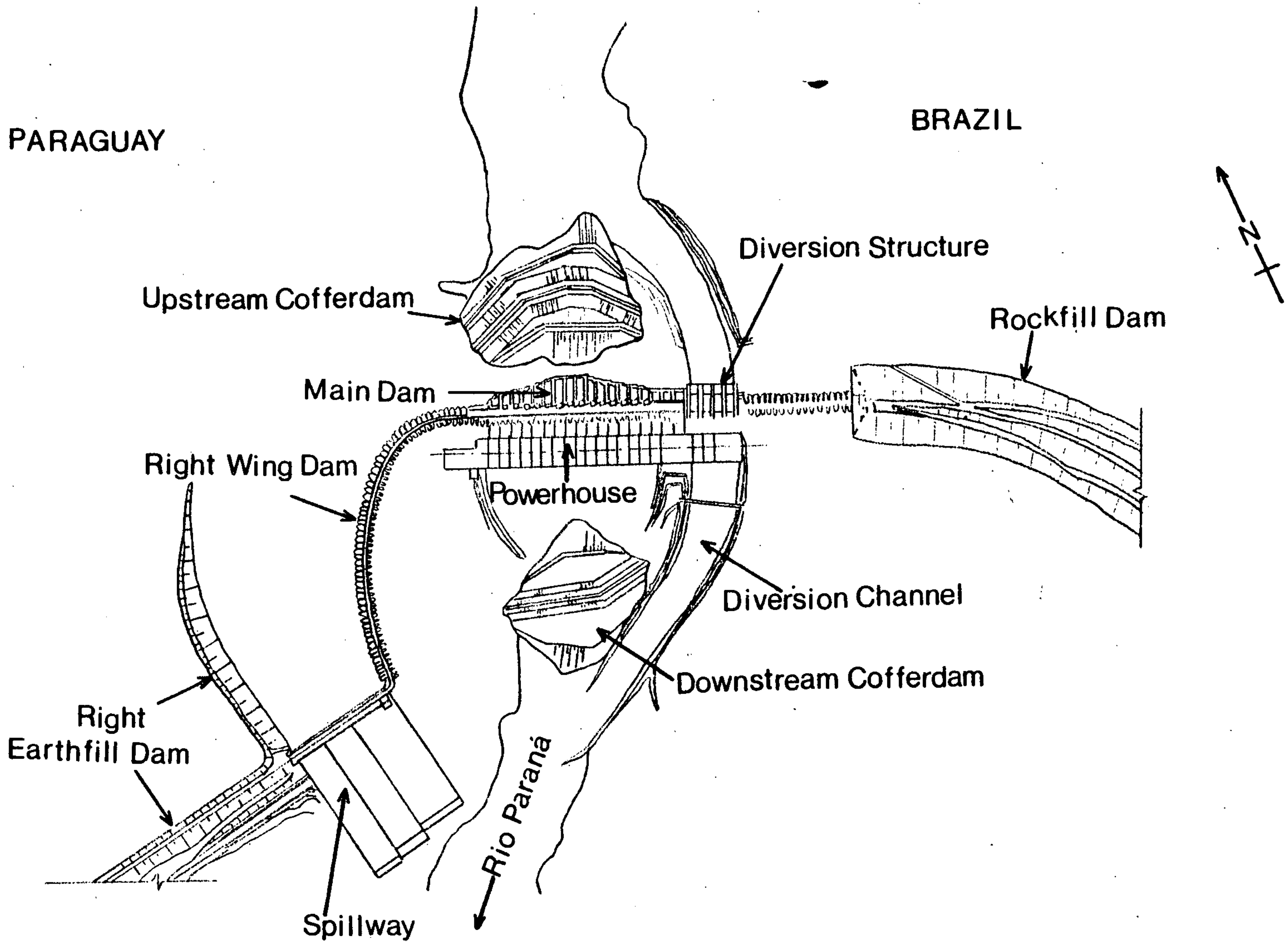


Figure 3.1 : UHE Itaipu - Project layout

the construction site by minibus. Booklets are available, and T-shirts are on sale with the motto "Itaipu, o maior obra do mundo" (the largest construction in the world). Major Brazilian journals regularly produce special Itaipu issues, usually updating the previous ones or emphasising different aspects of construction. All emphasise the grandeur of the project(339-343).

It was only after several years of study of the binational stretch of the rio Paranã, by both Brazil and Paraguay, that an exploitation agreement was made between the two governments. On 22 June 1966, the "Ata de Iguaçu" (Iguaçu Act) was signed between Brazil and Paraguay, providing for joint study of the water resources held in common. The agreement was implemented by a Brazilian-Paraguayan Joint Technical Committee set up the following February, but it was not until 10 April 1970, that a Convênio de Cooperação (Co-operation Agreement) was signed between ELETROBRAS and its Paraguayan equivalent Adminstración Nacional de Electricdad (ANDE) to establish the conditions for the technical and economic feasibility study of the development of the hydroelectric potential. This was to include a general appraisal of the multiple use of the water for power, navigation, human and industrial consumption, and irrigation(344).

Detailed field investigations of the Itaipu site were begun at the end of 1971. As a result of a preliminary report submitted to both governments in January 1973, they proceeded with negotiations for the Tratado de Itaipu (Treaty of Itaipu). This was signed in Brasīlia on 26 April 1973. It contained 29 articles which set out the regulations for the hydroelectric development of the rio Paranã from the Salto Grande de Sete Quedas (Salto de Guaīra) to the Brazilian city of Foz de Iguaçu(345).

The treaty created the entity Itaipu Binacional (see p.162) to co-ordinate the development of the civil works and the power station, and it also outlined a new structure for ELETROBRAS and its subsidiaries. It also ensured the Brazilian market for the power which is to be compulsorily purchased by FURNAS and ELETROSUL, who will then sell the power to the various electricity enterprises in the South and South East Regions of Brazil (see p.172). The Brazilian share of the power is primarily intended for the industrial South East of the country, with at least 50% of the power going to the city of São Paulo (346). However, some of the power is to go to the South region, and this has resulted in the speeding up of the electrical interconnection of these two hydrologically distinct regions. The deployment of power from the project is the mainstay of Brazilian electrical energy planning for the late 1980s, and all the current plans revolve around the power from Itaipu being available from the beginning of 1983(347). The GCOI plans have contingency allowances for a delay of up to six months of the entry into operation of UHE Itaipu, but there is no provision for any longer delay(348).

UHE Itaipu is being constructed on the rio Paraná, 190 km downstream of the Salto Grande de Sete Quedas. The average yearly flow (measured from 1931-1970) is 8 460 m^3s^{-1}, with a recorded maximum of 28 400 m^3s^{-1} and a minimum of 2 850 m^3s^{-1}. The catchment area for the project is 820 000 km^2. The net head of water at the dam site is 118.4 m. The civil structures will consist of a 1 234 m long concrete gravity main dam, maximum height 190 m, with a concrete volume of 6.6×10^6 m^3; a right abutment concrete dam, 998 m long, maximum height 65 m, concrete volume 0.7×10^6 m^3; a left abutment rockfill embankment, 1 984 m long, maximum height 70 m, and a left abutment earthfill dike, 2 294 m long, maximum height 30 m

The spillway, on the right abutment will have 14 radial gates and a discharge capacity of 62 200 m^3s^{-1}. There will be 18 water intakes in the main dam, each with a nominal flow of 698 m^3s^{-1}. The internal diameter of each penstock will be 10.5 m, and the length 110.2 m. The powerhouse will be situated at the toe of the dam and will house 18 Francis turbines (see p.115). The reservoir will be 190 km long and at maximum normal level will inundate 1 350 km^2. At absolute maximum this will increase to 1 460 km^2, of which 835 km^2 are in Brazil and 625 km^2 are in Paraguay. The maximum normal volume will be $29x10^9$ m^3.

The total quantities of the basic materials to be used are $1.9x10^9$ t cement, $0.3x10^6$ t aggregate, $4.0x10^9$ t sand and $214x10^3$ t steel for the concrete, plus $225x10^3$ t structural steel, the total concrete volume will be $12x10^6$ m^3. It is scheduled that $21x10^6$ m^3 of earth and $26x10^6$ m^3 of rock will be excavated(349). As of December 1978, the scheme employed a total of 31 300 persons, and had provided 8 923 housing units. In addition there were three medical assistance centres in operation, and a hospital under construction on the Brazilian side, together with four health centres, one medical assistance centre and a hospital in operation on the Paraguayan side. The scheme has also provided schools and shopping centres to meet the needs of the workforce.

The contract for the execution of the first stage of the civil works was awarded in 1975 to a consortium of Brazilian and Paraguayan companies. Five Brazilian companies formed the União de Construtoras Ltda. (UNICON), and six Paraguayan companies formed the Consorcio de

Empresas Constructoras Paraguayas S.R.L. (CONEMPA). Together they made the consortium UNICON-CONEMPA. This initial contract, valued at approximately US$ $300x10^6$, was for the excavation of the diversion channel, and for the spillway and right wing dam; construction of the left rockfill and earthfill dams; and construction of the main cofferdams for the Paranã river diversion. The river diversion was completed on schedule in October 1978. The diversion channel is 2 km long, 150 m wide and 90 m deep. $18x10^6$ m^3 of rock had to be excavated. The whole undertaking was an impressive achievement for Brazilian and Paraguayan engineering, the largest river diversion in the world accomplished with national technology and manpower(350).

In 1977, a contract was signed for the second stage of the civil works, consisting, primarily, of the construction of the main dam, spillway, rightwing dam powerhouse and erection bays. The opening of the diversion channel in October 1978, coincided with the awarding of a contract to the Consorcio Itaipu Eletromecânico (CIEM) for the delivery of the permanent operating equipment of 18 turbines and generators. By April 1979, the main cofferdams were complete, and the riverbed was drained in order to start on the excavation and foundation preparation for the main dam and powerhouse. The year 1979 was considered as decisive in the construction of UHE Itaipu, as the viability of the proposed start of generation depended upon the completion of riverbed work within the stipulated period of time(351,352).

The work on the site is supported by a number of integrated industrial complexes on both sides of the river. These consist of rock crushing facilities; artificial sand and special cement units and clinker mills; aggregate cooling and flaked ice units; concrete batching plants; an automatic overhead cable conveyor system, and tower cranes. Each complex has the capacity to pour 1 080 m^3 of concrete per hour. As the concrete must be placed at a controlled temperature of 7 °C, to prevent setting problems, in air temperatures which can be as high as 40 °C, it must be cooled prior to pouring(353). The two flaked ice plants, with a total capacity of 40 t are the largest in South America.

The electrical generation equipment will comprise eighteen Francis type turbines, rated at a maximum output capacity of 734 MW each, with a nominal continous rating of 715 MW. Nine of the generators will produce A.C. at a frequency of 60 Hz (for Brazil), and the other nine at 50 Hz (for Paraguay). The frequencies chosen have been debated with much argument and intractability(354). Although Paraguay will own half the generated power, Brazil will use nearly all of it. Consequently Brazil saw very little reason to generate it at a different frequency from the one at which it will be used. The effective capacity of the generators, at 95% efficiency, will be 700 MW, and the total installed capacity of the 18 machines will be 12.6 GW(355). The powerhouse will contain 56 step-up transformers to raise the voltage from the machine voltage of 18 kV to 500 kV or 750 kV for transmission. There will be, in addition, a further four turbines and generators, each with an installed capacity of 15 MW, to provide power for the project consumption.

The transmission system will consist of two primary sub-stations, one on each bank of the rio Paranã, 93 m downstream of the powerhouse. The power will be transmitted by five circuits over a distance of approximately 890 km, from UHE Itaipu to the city of São Paulo. There will be three in line sub-stations at Ivaipora, 310 km from UHE Itaipu, Itaberã, 266 km from Ivaipora, and Tijuco Preto, 313 km from Itaberã. Interconnection between the South and South East transmission systems will be effected at Ivaipora.

The nine 60 Hz generators will connect, through transformers, to three three-phase A.C. 750 kV circuits. This will be stepped down at Ivaipora to 500 kV, and again at Tijuco Preto, this time for retail distribution. The nine 50 Hz generators will generate A.C. which will be converted at a primary converter station to D.C. for transmission at a voltage of 500 kV to the São Paulo area. The D.C. will be converted to 60 Hz A.C. at a secondary converter station at Tijuco Preto. FURNAS is responsible for the financing and construction of the transmission system for the Itaipu project. At June 1976 prices, the direct investment required is US$ 1.5×10^9, and the total cost of the transmission system, including contingency and indirect costs was estimated at US$ 1.9×10^9.

The rio Paranã is used for river traffic and, although project construction is interfering with the navigation of the river at Itaipu, terminals are to be installed both upstream and downstream of the site. Ships will offload at the terminals, and the goods will be transported by road (to be constructed) and then reloaded back onto other ships. It is possible that a lock and canal may be constructed once the initial project is complete and traffic demands are established.

Table III.iii shows the allocation of the estimated total capital expenditure, which, in 1977, was expected to be US$ 7.6×10^9. It is interesting that the highest percentage of the costs goes in interest payment on loans(356).

Table III.iii : Allocation of Capital Expenditure for UHE Itaipu

Item	%
Land rights and relocation	2.99
Civil works	20.19
Permanent electromechanical equipment	14.16
Installations and support work	17.19
Navigation works	0.29
General administration	5.56
Engineering and supervision	5.56
Exchange adjustment	0.49
Unallocated costs	0.33
Interest during construction	33.24

Source : Information memorandum on Itaipu Binacional given to potential financers of a US$ 1.8×10^6 medium term loan, 3 April 1978.

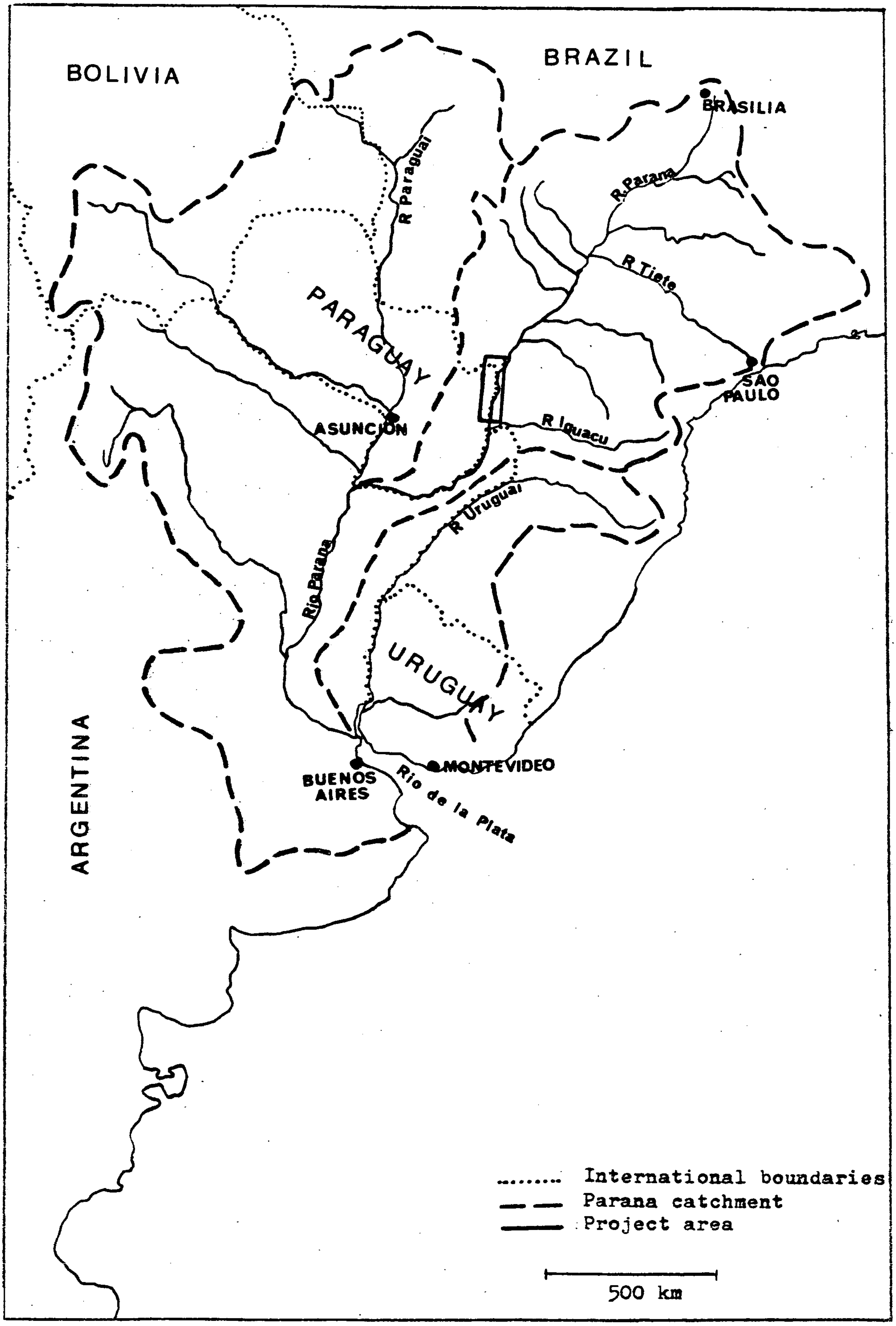
The costs of the project are constantly rising above the estimates. At September 1977 prices, the total cost was estimated at US$ 7.6×10^9(357); whereas at December 1977 prices, the total cost was estimated as US$ 8.7×10^9(358). The difference between the costs shows a 14.4% increase whereas the exchange rate between the dollar and cruzeiro only rose 6.9% between September and December 1977. By the end of 1978, the total investment in the project had been US$ 2.2×10^9 (December1977 prices), and in 1980, the total project cost was estimated at US$ 12.0×10^9 (1980 prices)(359). Despite the escalating costs, the Brazilian Government gives the project financial priority(360).

Estimates made in 1978 put the cost of this expensive project at US$ 690/kW, but the project is noteworthy for more than its size and cost. In the case of Paraguay it spells financial disaster(361). Paraguay's share of the cost is loaned from Brazil, who, in return, will purchase most of Paraguay's share of the power at an artificially low price for the next 50 years(362). As a consequence, Paraguay now wishes to renegotiate the terms of the agreement (363). Most of the engineering projects have been awarded to Brazil(364), and two thirds of the senior and middle level employees are Brazilian(365). The project has also made it more easy for Brazilians to colonise Paraguayan land close to the river, and even further inland, which has been unpopular with the Paraguayans(366).

There has been serious straining of international relations between Brazil and its downstream neighbour, Argentina, which claims that UHE Itaipu will detrimentally affect the operation of its own shared scheme with Paraguay, UHE Corpus. It is intended that UHE Itaipu be run as a peaking station, and this will affect the riverflow downstream considerably. On various occasions Argentina has threatened to raise the height of UHE Corpus, thus reducing the effective head at UHE Itaipu, and therefore its efficiency. Brazil then threatened retaliation with the installation of an extra two turbines, which would allow an even greater disruption to the riverflow downstream. Eventually an uneasy agreement was reached, and an accord, allowing operational flexibility, was signed by all three countries in October 1979(367).

Environmentally, the project will have a number of important impacts. The area to be inundated was assessed by a member of the Cary Arboretum, New York. He made a number of recommendations, including health protection measures, clearance of the forest, resettlement of peoples, and the creation of a wildlife park. He concluded that the problems which will be encountered will not be as disastrous as in many of the large African hydropower schemes(368). The greatest loss is considered to be the inundation of the Salto

Figure 3.2 : Location of UHE Itaipu



Grande de Sete Quedas by the tailwaters of the reservoir. According to some criteria these are the largest in the world, but they will be partially submerged by the reservoir(369).

Although it is disputed by ELETROBRAS and FURNAS that the power from UHE Itaipu is essential(370) (see p.156), there is no doubt that the most fortuitous outcome of the project is the unification of the electrical power industry which has resulted. Only the future will tell whether this enormous project will be the engineering triumph the Brazilians predict(371), or a financial disaster. Whatever the outcome, it will still be a landmark in the development of the indigenous Brazilian electrical power industry.

Rationing in the Electrical Power Industry

For the first fifty years of the Brazilian electrical power industry, all initiatives had been taken by the private companies. The principal ones in the South East, 'Rio Light' and 'São Paulo Light', had kept up with the growth in electricity demand until 1946, when, for the first time, the peak load equalled the installed capacity(372). Thereafter, the two companies were unable to satisfy all the demands made upon them, as peak demand outstripped increased capacity. (A full discussion can be found in Tendler(1968)(373)).

In the period after the Second World War, the problem of lack of generating capacity, coupled with a rapid increase in industrialization and the consequent expansion of the electricity market, meant that the production of electricity fell well behind the demand. This deficiency in generating capacity, added to the cyclic occurrence of severe droughts, resulted in rationing of supply and, in some cases, damage of electrical equipment. There was loss of industrial production and the deterioration of equipment, such as steel and glass-making furnaces. Electrically operated transport systems were seriously affected. The most serious rationing occurred in the cities of São Paulo and Rio de Janeiro.

The first electricity supply crisis had occurred in 1924-1925, as a result of the drought in the state of São Paulo which reduced the flow of the rio Tietê and its tributaries. This crisis was alleviated by the rapid execution of the UHE Rasgão project (see p.84), and the establishment of electricity consumption rules by the São Paulo state government. However, with the advent of the Second World War, and the consequent difficulties in importation of equipment, the installed capacity remained static whilst the demand grew.

This problem was aggravated by rising inflation. The private companies were unable to cope adequately with the crisis. 'The Light', being a foreign company, was more concerned with protecting its own interests than with helping the situation in Brazil (374), and it adopted a disguised rationing policy by repressing demand. The industrial expansion in São Paulo was retarded by 'São Paulo Light' which delayed satisfying demands for new connections. Another measure adopted by the company was to drop the frequency to 95% and the voltage to 85% of normal at peak periods of demand.

The situation became progressively worse, aggravated in the first half of the 1950s by a severe drought, which caused further rationing of the electricity supply. In the system of 'Rio Light', the electrical energy was almost entirely of hydraulic origin, from the rio Paraîba basin. With only one thermal station, UTE Flutante

Piraquê, the region suffered badly due to the low flows in the river and the lack of installed capacity. In order to minimise the crisis, the Conselho Nacional de Aguas e Energia Elētrica (CNAEE) authorised the electricity concessionaires to adopt restrictive measures to reduce electricity consumption, but it demanded also that the companies present plans for the expansion of their generation systems(375). This was not well received by the private owners, as they were loth to invest money in expansion(376). However, the 'Rio Light' did execute the Paraība-Piraī diversion, in order to supply water to the subterranean UHE Nilo Peçanha. In 1963, low flows in the rios Paraība and Piraī, coupled with the need to preserve the level of water in the Lages reservoir in order to guarantee the drinking water for the city of Rio de Janeiro, resulted in electrical rationing in that city. In addition power had to be supplied from the 'São Paulo Light' system via the Aparecida converter station. Four years later, in 1967, UHE Nilo Peçanha was inundated by a landslide and rendered completely inoperable. This resulted in stringent rationing in the city of Rio de Janeiro, with power supplied for only a few hours each day to this city of multi-storey skyscrapers and air-conditioning(377).

Since the early 1950s, the electrical power industry in Brazil has never kept pace with demand. The "economic miracle" of the 1960s(378) was accompanied by rapid industrialisation, expansion of the commercial sector, and a general rise in the standard of living. This was associated with an increase in the demand for electricity, but it is only now, with the construction of new large scale projects, that supply is catching up with demand. Although the major cities are assured of a reasonably constant supply of electricity, the slums (favelas) on the outskirts only have power through illegal connections, and the bulk of the rural population has no electricity supplies at all, despite the rural electrification programmes in progress(379).

Autoproducers

Autoproducers are those who generate electricity for their own private consumption. The owner of the first Brazilian hydroelectric power station, at Diamantina, used to supply power for the extraction of gravel, was an autoproducer. Since that time there have been a significant number of autoproducers in Brazil.. The electricity supply crises of the 1950s and 1960s resulted in an increase in their numbers and an expansion in their capacity. They were not restricted to factory owners, but extended to hotels, cinemas, and large buildings, where private generators were installed. Very few went as far as constructing their own hydroelectric power stations, but, of those who did, the majority were in the states of Minas Gerais and São Paulo(380).

The reasons given by autoproducers for generating their own electricity are various. In some cases there is no access to any other supply due to isolation, as in the Amazon Region. Others have, in the past, included excessive connection costs, insufficient guarantee of constant supply, and lack of faith in the regional suppliers ability to adequately meet their demands. In many cases, the autoproducers found it cheaper to generate their own electricity. In the sugar cane producing region of the North East of Brazil, bagasse is the energy source for almost half of the self generated power, whereas in the South East nearly half of the self produced power is of hydraulic origin. See table III.iv.

Table III.iv : Gross Autoproducer Generation, 1977 - GWh

Region	Hydro	F.Oil	Diesel	Bagasse	Wood	Others	Total
North	-	25.7	84.7	-	19.1	11.9	141.4
N.East	70.3	147.5	80.0	277.0	15.4	28.5	609.7
S.East	2 278.7	1 821.6	183.3	457.7	10.1	173.7	4925.1
South	309.7	451.8	35.0	36.0	177.0	37.0	1047.5
C.West	-	19.2	10.5	0.9	5.6	31.4	67.6
Brazil	2 658.7	2 465.8	385.5	771.6	227.2	282.5	6 791.3

Source : ELETROBRAS - DEME "Geração de Autoprodutores 1977/87", 1978.

Note : total gross production by autoproducers of 6.8 TWh represents 6.8% of the gross production of electricity in Brazil, in 1977, of 100.6 TWh(381).

From table III.iv and III.vi, it can be seen that the gross electrical energy production by autoproducers has maintained a slow, but steady, rise since 1962. This is expected to continue, despite strong discouragement from ELETROBRAS. In June 1977, in accordance with decree no.68,419, those autoproducers who were also connected to the concessionaire networks, supplying electricity from the national hydroelectric sources, had to pay a compulsory loan to ELETROBRAS to the value of 32.5% of the fiscal tariff. This compulsory loan will be recoverable after 20 years, and will be subject to interest of 6% per year. However, the autoproducer will only have to pay this loan if :

i. his installed capacity is greater than 500 kW, and he is using petroleum derivatives as a fuel source, and

ii. he is generating in an area where energy from a national source is available.

This compulsory payment does not therefore, affect autoproducers of hydroelectricity(382).

Autoproducers can exert a significant influence on the market of the government concessionaires operating in a given region. In an analysis carried out by CESP, published in 1974, it was revealed that 8% of the generation in the state of São Paulo was represented by autoproduction. This percentage, however, can vary depending on the relative expansion of the autoproducer and concessionaire generating capabilities. The percentage of the market held by autoproducers in 1974 was less than in 1973, because although there was in increase in generation of 11.6%, the concessionaires increased their generation by 17.7%. With the construction of the very large power stations, such as UHE Itaipu, the percentage produced by the autoproducers will decrease further, although their generating capacity is expanding. The participation of autoproducers in the concession areas varies widely, as seen in table III.v..

Table III.v : Autoproducer participation by Concession Area
São Paulo State, 1974

Area	Concessionary %	Autoproducer%
'Light'	79.1	20.9
CPFL	63.8	36.2
CESP	99.2	0.8
Others *	77.6	22.4
S.P.State	92.2	7.8

* Only includes those concessionaires with autoproducers operating in their area of concession.

Source : CESP "Estado de São Paulo - Analise e acompanhamento do mercado de energia elétrica dos autoprodutores" Diretoria de Distribuição, 1974.

In the CESP concession area, autoproducer generation is almost non-existent, but in the area of concession of 'The Light', by tradition an inefficient supplier, 20% of the generation is by autoproducers. This is significant, when the industrial market is considered. In 1974, 22% of the total industrial consumption of electricity in São Paulo state was by autoproducers(383).

Table III.vi : Installed Capacity,

Year	Autopr. * GW	Autopr. % of total	Brazil GW
1965	0.877	10.6	7.411 #
1978	2.820	10.1	25.229 $
1985+	3.233	6.2	49.042 $
1995+	3.474	6.0	54.769 $

+ Estimated

Source : * ELETROBRAS - DEME 24/1/80

ELETROBRAS Report 1978

$ Plano 95

There is one company involved in autoproduction which is refusing to change its policy of electricity production for its own consumption, and that is the Companhia Brasileira do Aluminio (CBA), a subsidiary of the Grupo Votorantim. CBA operates a fully integrated system, from the CBA owned bauxite to the finished aluminium cast, rolled or extruded product. It runs one 83 000 tonne smelter, and it supplies 75% of its own power from five hydroelectric power stations. A sixth is under construction. Up to mid-May 1980, the company had consumed a total of 621 GWh in 1980, of which 473 GWh were CBA generated, and 148 GWh purchased.

The company commenced smelting in 1955, when it purchased power from 'The Light', but, by 1958, it had started to generate some of its own electricity. It was found to be cheaper, and a more reliable source of supply. However, in order to maintain a connection to the national network, in case of breakdown of its own supply, the company is obliged to purchase some power from 'The Light', even though it is more expensive, and often not required. CBA has constructed four hydroelectric power stations on the rio Juquia-Guaçu, and a fifth is under construction. In addition the company purchased UHE Itupiraranga from 'The Light'. A further three hydroelectric power stations stations are planned, one on the rio Paranapanema, (120 MW), and the other two on the rio Juquia-Guaçu.

The company is, by law, forbidden to sell any of its surplus power, and it must purchase power from 'The Light' at a price of 15 mill/kWh (1980 price). It uses this compulsory purchase of power in order to regulate its reservoirs, purchasing more during the dry season in order to maintain levels. The cost of its own power is calculated as being 4 mill/kWh, even allowing for depreciation on structures and equipment(384).

Government Intervention in the Electrical Power Industry

One of the consequences of the deficit in the production of electricity was the start of government intervention in the electrical power industry. In the 1950s, the Federal Government was making ambitious, pioneering plans for national development projects which would create a need for more electrical energy, and it was anxious to be closely involved (see table III.vii). The very first state government participation in the Brazilian electrical power industry occurred in Rio Grande do Sul. Until the middle of the

Table III.vii : Government Participation in Electrification

Date	State	Company	Initial Purpose
1943	R.G.do Sul	CEEE	Dev. Hy. Pot. & Coal Res.
1945	N.E.Region	CHESF	P.Afonso & Dev. rio S.Francisco
1952	M.Gerais	CEMIG	Electr. of state
1957	M.Ger. & S.P.	FURNAS	UHE Furnas
1957	Paranā	COPEL	Electr. of state
1962	Brazil	ELETROBRAS	Braz. Electr. policy
1966	S.Paulo	CESP	Co-ord. state services

1940s, as common in other states, only the major urban centres had public electricity services of an acceptable standard. In the rest of the state, the municipal governments and a few enterprises struggled with the problem of electricity supply without either sufficient financial or technical resources. On 16 February 1943, the Comissão Estadual de Energia Elētrica (CEEE) was created in order to develop and operate a general electrification plan for the whole state, utilizing its hydraulic potential and coal reserves. A pioneering plan, the Plano de Electrificação do Rio Grande do Sul was presented to the CNAEE and the Divisão de Aguas of the Ministērio da Agricultura for approval.

In September 1948, the first power station to be entirely planned and constructed by the Comissão, the 1.5 MW UHE Passo de Inferno, commenced operation, supplying power to the industrial areas of São Leopoldo and Caixas do Sul. Other small hydroelectric power stations were to follow. A state law, no.1231, of 29 November 1950, made provision for major financial resources for the Plano de Electrificação through the creation of the Taxa de Electrificação (Electrification Rate). This was later abolished with the instigation of countrywide tax reforms in 1969, and subsequent funding came from the Fundo Estadual de Investimentos (State Investment Fund). From its inception in 1943, the Comissão was gradually transformed and in 1963 became a mixed economy society, called the Companhia Estadual de Energia Elétrica, although it retained the acronym CEEE(385).

As described on page 99,the Companhia Hidrelétrica do São Francisco (CHESF) was created in 1945, in order to build UHE Paulo Afonso. In 1947, with the "awakening of the national conscience" to the problems of the North East, the Federal Government passed a decree specifying the role of CHESF as that of developing the stretch of the river between Juazeiro and Piranhas, in order to supply power to the concessionaires within a radius of 450 km of Paulo Afonso(386).

Centrais Elétricas de Minas Gerais S.A. (CEMIG), was founded in 1952 by the government of Minas Gerais. It was initially established as a holding company, incorporating the shares held by the state government in the Companhia de Eletricidade do Médio Rio Doce, Companhia de Eletricidade do Alto Rio Grande, and Central Elétrica de Piau S.A., which all became subsidiaries of CEMIG. It was a successful example of a mixed economy enterprise, and it proved to be a good solution to the problem of expansion of electricity supply, required due to rapid national development(387).

For the first four years of operation, CEMIG concerned itself with the construction of four new hydroelectric power stations and their respective transmission networks, thereby adding a further 168 MW to the system and nearly doubling its installed capacity. The decisive factor heralding the emergence of CEMIG had been the lack of available installed capacity. At the time there had been a total of 439 power stations supplying electricity to 688 localities. The total state installed capacity was 13 MW, and the average installed capacity per inhabitant was no more than 25 W(388).

In 1957 CEMIG began construction of UHE Três Marias, with the help of the Companhia do Vale do São Francisco. At that time, the Três Marias dam was the fourth largest earth dam in the world, and it was built under difficult conditions due to its isolated location. The dam allowed partial regulation of the rio São Francisco, which permitted the addition of an extra 400 MW of installed capacity at UHE Paulo Afonso(389). It improved the navigability of the river. and It added a further 520 MW to the installed capacity of the region, and this stimulated further development of the electro-metallurgical and electro-chemical industries(390).

In the first ten years of its operation, CEMIG transformed the energy scene of Minas Gerais, by increasing the installed capacity by a factor of 30, to 369 MW, and rescuing the industrial development of this mineral rich state from the virtual strangulation to which it was subjected by the lack of adequate supplies of electricity. The accelerated development of the state into a powerful one, with a large and diverse industrial base, is due largely to CEMIG. It was also responsible for pioneering rural electrification, when in 1962, it created the Eletrificação Rural de Minas Gerais S.A. (ERMIG) in order to operate a dynamic programme of state rural electrification(391), and to provide approximately 10 000 farmers with electricity. In no other area has been seen, in such an immediate form, the influence of electric energy on the process of social evolution as was seen in the area served by CEMIG and ERMIG.

The state became the fulcrum of the activities of the revolutionary movement the "Movimento de 64", which led the Brazilian nation on its development trajectory after the revolution(392).

In recent years CEMIG has begun to wield considerable influence in the Brazilian electrical power industry, by operating eleven large hydroelectric power stations and several smaller ones. It is in the process of completing UHE São Simão (2 680 MW) on the rio Paranaiba(393). However, the most influential of the state electricity utilities is the Centrais Elétricas de São Paulo S.A. (CESP). São Paulo state is the major economic and industrial centre in Brazil, but, in the early 1950s, the electricity supply industry was not keeping pace with industrial development, and it was feared that the continuing rapid economic development of this state would be threatened by lack of electricity. Other sectors of the Paulista economy urged the state government to help alleviate the situation by involving the state in the construction of generating stations and high voltage transmission lines(394).

Until that time, the greater part of the electricity supply to São Paulo state had been supplied by 'São Paulo Light' and CPFL but, in 1949, the state government began the hydroelectric development of the rio Paranapanema. The mixed economy society, Usinas Elétricas do Paranapanema S.A. (USELPA), was created by state law on 19 August 1953. Seven years later it was amalgamated with the Companhia Hidrelétrica do Rio Pardo (CHERP) in order to study the power development of the lower and middle reaches of the rio Tietê. There were three other companies operating in the region, Centrais Elétricas de Urubupungá (CELUSA), Bandeirante de Eletricidade S.A. (BELSA), and Companhia de Melhoramentos de Paraíbuna S.A. (COMEPA).

It was decided that if all were combined it would offer a more integrated and efficient system of electricity generation and distribution. As a result, the Companhia Energética de São Paulo (CESP) was given authority to operate as an electrical energy enterprise in December 1966, and, one month later, all the concessions of USELPA, CHERP, CELUSA, BELSA and COMEPA were transferred to CESP(395).

Until recently, the rio Paranã river system had been ignored by the electricity concessionaires because of its great distance from the industrial market, although, as early as 1952, the Comissão Interstadual da Bacia do Paranã-Uruguaĩ (CIPBU) was created to make studies of the rio Paranã and the rio Urubupungã. In 1957, a state law founded the Companhia Paranaense de Eletricidade (COPEL), a mixed economy enterprise of which 60% belonged compulsorily to the state of Paranã. It was to effect a systematic study of the existing generation sources and the probable demand. At that time, the priority was,and still is, given to the supply of power to the industrial South East. As a result, COPEL and USELPA made an agreement over the joint development of the rio Paranapanema, with 40% of the power to go to go to the state of Paranã. This was one of the first examples of inter-state co-operation(396).

Other major examples of government participation in the electrical power industry are FURNAS, created in 1957 (see p.100), and ELETROBRAS, created in 1962 (see chapter 4).

Frequency

The choice of various frequencies for generation transmission in Brazil reflected the non-integrated electrical power system which had spontaneously developed in the country. At the beginning of the nineteenth century, when Brazil began the more intense development of its hydraulic energy, Europe had already adopted a frequency of 50 Hz, and the USA a frequency of 60 Hz. This frequency difference was reflected in the equipment imported from Europe and imported from from the USA. 50 Hz and 60 Hz became the dominant frequencies in Brazil, but others were adopted, such as 42 Hz in Curitiba, 40 Hz in Jundaī and 125 Hz in Petropolis(397).

The need to unify the frequency, came from the need to optimise the use of energy resources within the country, as well as for the economic convenience of standardization of equipment. This was apparent in the case of UHE Paulo Afonso, where generation was at a frequency of 60 Hz, but one of its major planned markets, Recifē, operated at a frequency of 50 Hz. This resulted in an apparent excess generating capacity at UHE Paulo Afonso and a lack of supply in Recifē(398).

The first studies of frequency diversity in Brazil date back to 1929, when the Grupo Light anticipated the need to interconnect the two systems of Rio de Janeiro and São Paulo, the former operating at 50 Hz and the latter at 60 Hz. Although the studies were not followed up, the question was not ignored. In 1938, article 23 of the Decree-law no. 852 stated that:

> "...electric energy obtained by means of transformation of hydraulic or thermal energy, will be produced in order to supply the Brazilian territory in the form of three phase alternating current at a frequency of fifty cycles (50 Hz)." Furthermore "...the electricity enterprises, individual or collective which supply electric energy to public services or for public use, or make a business of energy, must have all their installations function in accord with the stipulation in article 23, within eight years".

In other words, a move had been made to unify the Brazilian supply frequency in 1938, but this was not successful. Only autoproducers were excluded from the obligation to unify the frequency, but the eight year time limit imposed was not respected, and, in May 1942, it was extended in accordance with article 6 of decree-law no.4295 "for a period to be suitably fixed". At the same time, this decree made it possible for new installations to use both the 50 Hz or 60 Hz frequency(399).

The advent of the Second World War made the acquisition of equipment from Europe more difficult than from the USA, and 60 Hz equipment began to predominate. In 1948 the Brazilian ambassador in the USA, Mauricio Nabuco, wrote to the Brazilian President, E.G. Dutra, alerting him to the need to unify Brazil's frequency to 60 Hz. He stated, without explanation, that it was 16% more efficient than operating at a frequency of 50 Hz, and, because the USA operated at 60 Hz, any equipment for use at 50 Hz ordered from the USA had to be specially made*. This letter acted as a further stimulus for frequency studies. It was decided to consult the interested parties - the electrical enterprise syndicates, the large concessionary companies, and the engineering clubs of Rio de Janeiro and São Paulo. They were posed the following questions :

i.The problem of standardization of frequency is of national importance, and, as such, a single frequency should be fixed for all the electrical systems in the country?

---

* It is interesting to conjecture that the ambassador had suffered pressure from the electrical goods supply industry in the USA, in order to protect their market in Brazil.

ii. Would it be a satisfactory solution to maintain the frequencies at 50 Hz and 60 Hz, by zones, in accordance with actual predominance?

iii. What advantages are there to a single standard frequency?

iv. Which frequency should be chosen, considering the technical and economic aspects of the problem?

v. What damage will occur to the concessionaires and consumers operating at the non-chosen frequency?

vi. How can this damage be avoided?

vii. What conversion programme should be followed?

viii. How can it be efficiently carried out with least inconvenience?

ix. What reasonable time period would be required to accomplish this?

x. What would be the costs of conversion (to an order of magnitude) from 50 Hz to 60 Hz and vice versa?

The response to the questionnaire was good, but there was much variation in the answers. The major interested party was the 'Grupo Light', which employed a group of consultants to study the question. They finally gave their answer to the questionnaire in April 1950, when they recommended 60 Hz as the standard frequency, and concluded that it would take five years to convert the Rio system to 60 Hz, at a cost of US\$ 27×10^6 or, approximately, US\$ 50 per consumer (1950 prices).

In 1954, the projected law for the Plano Nacional de Eletrificação was before Congress, and, at the same time, it was proposed to adopt the standard frequency of 60 Hz as the cheapest and quickest to execute. However, in 1957, article 46 of decree no.41019 did not unify the frequency, but adopted the two frequencies of 50 Hz and 60 Hz as standards in accordance with zones delimited by the Conselho de Aguas. In 1961, the Conselho set up a Comissão de Uniformização de Frequência, which recommended the creation of a Comissão Especial. The 1963 CANAMBRA report to the Comitê Coordenador da Região Centro-Sul recommended the organization of technical personnel for the supervision of the frequency conversion programme in the system of the 'Grupo Light'(400).

In 1964, ELETROBRAS created a Grupo de Trabalho para Mudança de Frequência (Work Group on the Change of Frequency), which presented a four stage plan to be undertaken from 1964 to 1967. It recommended :

i. approval of the Programme for frequency change in the Guanabara region, including the state of Rio de Janeiro,

ii. that ELETROBRAS should be co-ordinator of the change,

iii. confirmation of the Escritório Técnico para Conversão de Frequência (COFRE), set up by the government of Guanabara state, as the entity especially responsible for examining the installations of consumers in that state, and

iv. that 'Rio Light' takes the necessary steps to expand its system at the same time as making the conversion.

Finally, 60Hz was adopted as the national frequency on 6 November 1964, in accordance with law no.4454. Except in exceptional circumstances, all new installations were to operate at this frequency. It was not until 1966, however, that the responsibility for the works necessary for the conversion finally fell upon the users of electricity, according to resolution no.3216, of 21 March 1966. In order to accelerate the programme of change, the MME published law no.407, in May 1967, stating that :

i. ELETROBRAS was designated technical and financial co-ordinator for the frequency conversion programmes,

ii. ELETROBRAS was authorised to maintain contacts and to assign conventions for the standardization of the frequency in government and private bodies, Federal and state, in the states of Guanabara, Rio de Janeiro, Espirito Santo and Rio Grande do Sul, and

iii. the concessionaires were given responsibility for elaboration and execution of the frequency conversion plans.

In October 1967, ELETROBRAS published the Plano Guia (Guide Plan), with the intention that the execution of the frequency change plans be complete by the end of 1971. Prior to publication of law no.407, only 3% of the 'Rio Light' system had been converted, but within two years this had risen to 53.2%, and by the end of 1970, all of the Guanabara region was using a frequency of 60 Hz.

The conversion programme forecast the construction of various large scale transmission networks, such as from UHE Furnas to Rio de Janeiro. However, certain factories, which operated on a 24 hour day, seven day week, presented problems, as damage would occur if they interrupted production. This was overcome by means of a double supply, at both 50 Hz and 60 Hz, allowing a gradual conversion. The situation in Rio de Janeiro was not helped by the total shut down of UHE Nilo Peçanha due to a landslide in 1967 (see p.121). A line from UHE Furnas had not been completed, and therefore to maintain supply to Rio de Janeiro, a connection was made with the CEMIG system, until UTE Santa Cruz, an experimental thermal station, was opened. The final stage of the Guanabara state conversion took place in August 1970. It was in a highly industrialised area, which represented 25% of the total demand. The conversion took thirty days(401).

The last region of Brazil to undergo frequency conversion was the state of Rio Grande do Sul. It finally became necessary, in order to effect an interconnection between the concession area of CEEE and the systems of the South East region. In some very isolated areas, with diesel generation, the change was deemed unnecessary. On 22 July 1969, the Departamento de Conversão de Frequência (DECOFRE) was established by ELETROBRAS, ELETROSUL and CEEE in order to plan the conversion(402). The process took eight years, with final conversion being completed in 1977(403).

The standardization of the Brazilian operating frequency to 60 Hz is perhaps the single greatest factor in the creation of the current perspective of the Brazilian electrical power industry. It has paved the way for interregional connections, and has established a single uniform power system for the generation and transmission of electrical energy. In addition it has made national electricity supply planning possible and furthered economic development by national energy sharing. International sharing of electricity however, presents a problem, as Argentina, Paraguay, and Uruguay all operate at a frequency of 50 Hz.

CHAPTER 4

ELETROBRAS

The electrical power industry in Brazil is under the jurisdiction of the Ministério das Minas e Energia (MME), which is responsible for all energy matters. It operates through the Departamento Nacional de Aguas e Energia Elétrica (DNAEE) and through Centrais Elétricas Brasileiras S.A. (ELETROBRAS). The DNAEE has the responsibility for the granting of concessions to build power stations, and establishes the electrical power rates. It also oversees the operations of the concessionaire electricity companies. ELETROBRAS is a corporation, with both government and private capital, and is in charge of the overall planning, financing and co-ordination in the electrical power industry. In addition it supervises construction programmes, as well as the expansion and operation of the generation, transmission and distribution of electricity(404,405).

Historical Background

In 1904, decree no.5407, established broad guidelines for the countrywide development of the hydraulic potential available for the production of electricity. This was followed, in 1906, by law no.1167, which gave authority to the President of the Republic to develop a water code (Código de Aguas) to be submitted to the Brazilian Congress. The draft code was submitted in November 1907, but remained dormant in the Comissão de Constituição e Justiça da Câmara (Parliamentary Commission for Constitution and Justice) for four years, until the left wing faction proposed that it be enacted into law. As a result it was directed to the Senado (Senate) to be studied in conjunction with the proposed Código Civil (Civil Code). However, the Câmara Alto (Upper Chamber) of the Senado preferred the two codes to remain separate, and the proposed Código de Aguas was sent to the Câmara dos Deputados (Chamber of Deputies) where it was not reconsidered until 1916.

The unamended 1907 proposal was given a second reading in December 1917, but the voting on the motion was not ratified until August 1920. A third discussion took place at the end of that month, and the proposal, with amendments, was then returned to a special commission, and the matter was dropped until the dissolution of the Congress in 1930.

After the 1930 revolution, a decree was published, no.20 395 of 15 July 1931, which prevented any act of alienation, tranference or harnessing of water courses. Finally, in June 1934, in accordance with decree no.24 643, the Código de Aguas came into force. This outlined the use of water resources, and gave a sense of unity to the electrical power industry. It established the legal system of the payment for servicing through pricing, but it was not until 1957 that full legal regulation of the activities of the organizations subject to the Código de Aguas came into force(406).

The Ministério das Minas e Energia (MME) was created by law no.3782,in 1960, in order to administrate Brazilian energy policy, previously a function of the Ministério da Agricultura. The role given to the MME was of fundamental economic, social and political importance - the planning and exploitation of the Brazilian energy and mineral resources. In the same year the Conselho Nacional de

Aguas e Energia Elétrica (CNAEE), the Comissão Nacional de Energia Nuclear (CNEN) and the Departamento Nacional da Produção Mineral (DNPM) were also created.

ELETROBRAS was authorised by law no.3890, of 25 April 1961, and this was followed in 28 November 1962 by law no.4156, which established the Empréstimo Compulsório in favour of ELETROBRAS (see p.63). The MME was reorganised in 1965, when law no.4904 created the Departamento Nacional de Aguas e Energia Elétrica (DNAEE). It was made responsible for the planning, co-ordination and execution of hydrological studies throughout Brazil. In addition, it was responsible for the control of, and the revenue from, water resources and electrical services. Soon after the creation of the DNAEE, CNAEE was abolished. Since 1962, many of the essential executive roles for the development of the Brazilian electrical power industry have been performed by ELETROBRAS, with the MME and CNAEE, followed by the DNAEE, providing secondary assistance(407).

ELETROBRAS

Until the creation of ELETROBRAS, the Brazilian electrical power industry had been in decline for some time. From 1934 until 1945, the industry had suffered from the restrictions of the Código de Aguas, followed by the effects of the Second World War and the consequent equipment importation difficulties. In the following years, the close association between private and government initiative in the electrical power industry was tranquil, but it was soon succeeded by the stagnation of private initiative in the electrical power industry and the emergence of the mixed economy societies (408). It was, therefore, in an atmosphere of wrangling, between government and private enterprise, over generation, distribution, deficiencies in electricity supply, and the rate problem that ELETROBRAS was eventually created(409). The process had taken eight years.

In 1954, a motion was presented to the Congresso Nacional (National Congress), under President Getulio Vargas, proposing the creation of an organisation which would determine the operation, either directly or by means of controlled and united enterprises, of the electrical power industry. This body would also be responsible for undertaking studies and projects, the financing of construction and operation of power stations, transmission lines, and the distribution of electricity.

The motion, no.153, stated :

> "The mixed capital society not only offers the directors the freedom of action vital to the accomplishment of the tasks to which they are committed, but it also allows the Federal Government to associate itself, in a simple way, with the states, Federal District and municipalities, in order to combine the financial resources, based on revenue, to solve the electrical energy problem"*.

However, this proposal was left for a further seven years, until the Congresso Nacional, under President Jãnio Quadros made it law on 25 April 1961. This was followed by a decree in February 1962, in which the Minister of the MME was authorised to set up a work group to study the constitution of such a mixed economy organization. The studies were soon complete, and ELETROBRAS, created at a General

---

"A sociedade de capital misto não sõ proporciona aos dirigentes a liberação de ação indispensável ã realização das tarefas que lhes sejam cometidas, mas tambem permitirã ao Governo Federal associar-se, de forma simples, aos Estados, do Distrito Federal e dos municípios, para a conjugação dos recursos financeiros do origem fiscal destinadas ã solução do problema da energia elétrica"(410).

Assembly of the CNAEE, was launched with an initial capital of Cr$ $3x10^9$ (1962 prices), which were totally subscribed by the Federal Government.

From its inception ELETROBRAS has been a holding company, and the nucleus of a group of concessionaires which are able to count on a fair degree of administrative autonomy, but at the same time they generate resources which enable ELETROBRAS to be the principal financing agency in the electrical power industry(411).

In the seven years that the ELETROBRAS proposal remained in the Câmara, some other Federal and state companies had been established and were engaged in constructing or operating sizeable power stations (see p.100). Since that time, however, ELETROBRAS has progressively absorbed national and foreign enterprises operating in the electrical power industry. This has been an irreversible process, and has strongly influenced the present structure of the Brazilian electrical power industry.

The creation of ELETROBRAS was not welcomed by the private electricity utilities, who were concerned that ELETROBRAS might interfere with their autonomy of operation. Once the company had been established, they tried to ensure that it became involved in areas far removed from their concession areas. A syndicate of electrical industries in São Paulo suggested that ELETROBRAS concentrate on development work in isolated regions of the country, and the FURNAS president recommended that ELETROBRAS concern itself with the construction of a power network in Brasília, which had just been established as the new Federal Capital(412). It soon became apparent, however, that ELETROBRAS was not going to restrict itself to such suggested areas of operation.

In the first edition of the ELETROBRAS journal "Revista Brasileira de Energia Elétrica", the editorial page was given over to an interview with the new Minister of the MME, Gabriel Passos. It was entitled "Servir ao Brasil e não servir-se do Brasil" - "To serve Brazil, and not to use it". He was quoted as saying :

> "... I am certain that in the very near future, when we look back on what has gone before, we shall see a notable change in the Brazilian electricity policy. Until now, this policy has been dictated by the interests of particular large concessionary enterprises, but, in future, it will be dictated by ELETROBRAS, exclusively, according to national interest".

A few months later the same journal quoted part of a speech, made by President Getulio Vargas to the Congresso Nacional in April 1954, soliciting the creation of ELETROBRAS.

> "The creation of ELETROBRAS is one of the measures necessary in order to enable the Government to deal appropriately, with the grave problem of public supply of electricity"(414).

In 1962, at the time of the creation of ELETROBRAS, the electrical power industry was under severe pressure from growing demand. It was failing to keep up with industrial development, and the situation was exacerbated by inflation of some 60% per year. The expansion indices of the electricity sector soon showed, that, despite the economic and social drawbacks current at the time, ELETROBRAS was the best instrument to provide an electrical energy policy for Brazil; its ideology was payment of service through charges, as opposed to the previous system based on historic cost (see p.60)(415). The success of ELETROBRAS may be seen from Table IV.i.

Table IV.i : Total electricity Consumption compared with Population

Year	Consumption TWh	Population $x10^6$
1950	-	-
1962	21.9	75.3
1975	64.1	110.1
	Factor of Increase	
1950-62	-	-
1962-75	2.92	1.46

Source : 75 anos p.54

The project outlined by President Getulio Vargas, in 1954, stated :

> "ELETROBRAS will operate directly, or through organized subsidiaries or associated companies. It will function, therefore, as a holding company for the Federal enterprises, and will be entrusted with the federal services forecast in the Plano Nacional de Eletrificação for the various regions in Brazil. It will also be associated with the enterprise, or enterprises which produce the materials, machines and indispensible equipment for the fulfillment of this national plan. If private initiative becomes disinterested in such an enterprise, a subsidiary will be created to take its place...The institution of Centrais Elétricas Brasileiras S.A. - ELETROBRAS, implies the adoption of a new economic direction for Brazil, which already has, to its credit, the creation of a steel industry, and is endeavouring to find a solution to the problem of petroleum..."(416).

At the end of its first fifteen years, ELETROBRAS celebrated the beginning of its operation in the electrical power industry. The installed capacity in Brazil rose from 5.8 GW in 1962 to 21.7 GW in 1977. It was through ELETROBRAS that the Brazilian Government began to establish the "basic sector of national life". Since 1964, the electrical power industry has had administrative continuity which, for the first time, has permitted the development of long term planning programmes. The present form of ELETROBRAS has developed as the result of this continuity, and of the support provided by the Federal Government.

> "Without this continuity, without this careful planning, without this sense of priority, without the relative autonomy with which ELETROBRAS has acted during its existence, little would have been able to be done".

In an industry where the construction of a power station, or the extension of a transmission line has great political-electoral significance, it is difficult for a government organised enterprise to resist the resultant pressures. But, in its first fifteen years, ELETROBRAS was reasonably successful in being impartial.

> "It has been an enterprise of technical experts, given over to them, directed by them, and for this reason it is able to commemorate with jubilation the fifteenth anniversary of its existence"(417).

From the very beginning, the planning methods which ELETROBRAS adopted were innovative. At the same time as coping with the reorganization of that section of the electrical power industry, over which it had assumed control, it also established the Comitê Coordenador dos Estudos Energéticos da Região Centro Sul, which was partly financed by the United Nations Development Fund, in order to study the hydraulic potential of the South East region (see p.185), and the development of the energy market so as to prepare a basic fifteen year plan.

Today, in association with DNAEE, ELETROBRAS is the legal organ through which the Brazilian Government acts on matters concerning the electrical power industry. The administration of the DNAEE is direct, through the MME, and its workers are public employees. ELETROBRAS, however, is a company and, although the major shareholder is the Federal Government, it is essentially autonomous, with relative freedom in financial decisions and employment of personnel. It is. however, the role of the President of the Republic to appoint the President of ELETROBRAS. In routine activities, the company has complete freedom, but those decisions in the electrical power industry which have a direct bearing on the Brazilian economy are made by the Federal administration as a whole(418).

Whereas, DNAEE is responsible for the granting of concessions for the construction of power stations, the establishment of electrical power charges, and the overseeing of the operations of the concessionary companies, ELETROBRAS has a number of other functions. Principally developed as a holding company, it also controls the operations of its four major subsidiaries, in which the Federal Government is also the major shareholder (see p.149). It is also a financing agency, supporting its subsidiaries and other electricity companies, principally state owned ones. It also has responsibility for the co-ordination of foreign investment programmes, in which it guarantees loans and receives funds which are then transferred to the other electrical power companies.

In its role as a co-ordination and administration agency, ELETROBRAS advises the MME on the establishment of long term expansion policies in the electrical power industry (see p.200), and it guarantees the necessary funds for the investments in such expansion. It also co-ordinates the interconnection of different electrical systems (see p.173), and promotes agreements with neighbouring countries, for the purpose of electricity purchase or exchange(419).

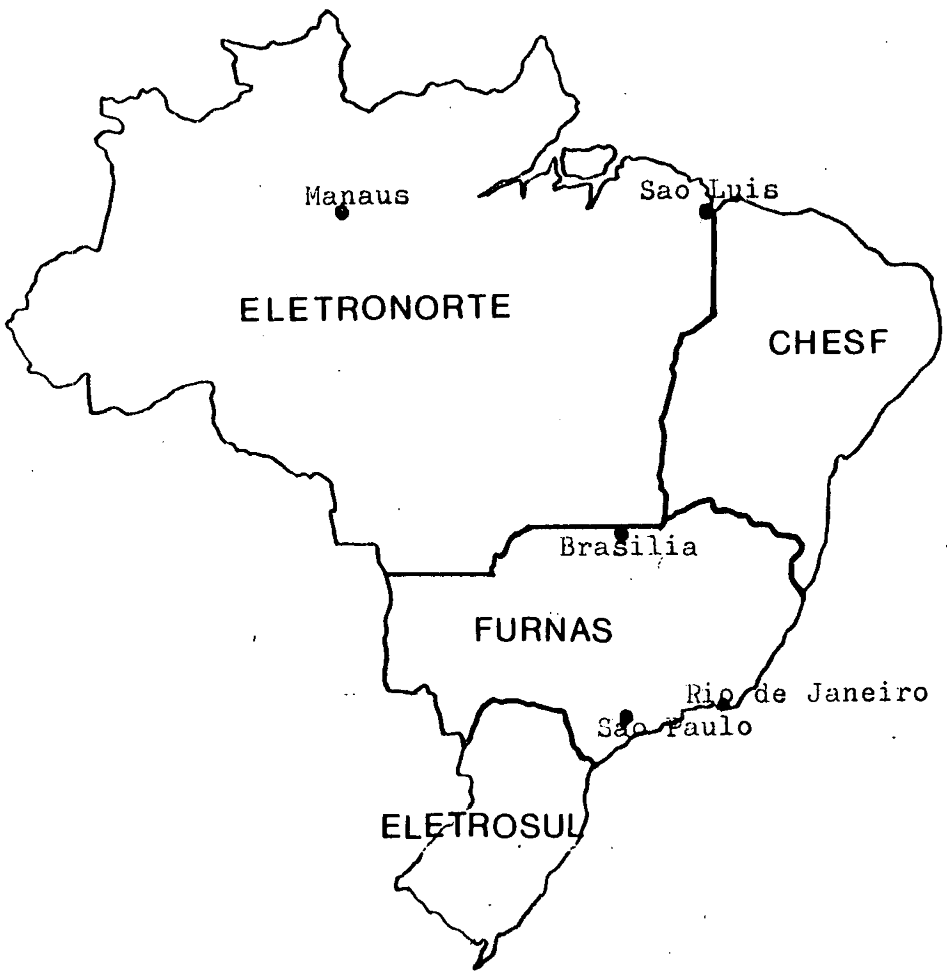
ELETROBRAS Subsidiaries and State Enterprises

As a holding company, ELETROBRAS operates through four regional subsidiaries FURNAS, ELETROSUL, ELETRONORTE and CHESF, all of which are responsible for the generation and bulk transmission of electricity. It also holds the controlling interest in three distribution utilities, Companhia de Eletricidade de Manaus (CEM), Espirito Santo Centrais Elētricas S.A. (ESCELSA), and Companhia Brasileira de Energia Elētrica (CBEE). In addition, it is the major shareholder in the Centro de Pesquisas de Energia Electrica (CEPEL) and 'The Light'. (A list of the other principal associated companies may be found in appendix 3).

Politically, Brazil is subdivided into five regions, the North, North East, Centre West, South East and South (see p.16), but it is only subdivided into four electrical regions, as shown in figure 4.1. These regions were originally defined in 1973, in accordance with the Lei de Itaipu (see p.173). The area of activity of FURNAS was defined as covering the states of São Paulo, Minas Gerais, Rio de Janeiro (and Guanabara), Espirito Santo, Goiâs, south of latitude 15°30'S, Mato Grosso south of latitude 18°S, and the new Federal District.

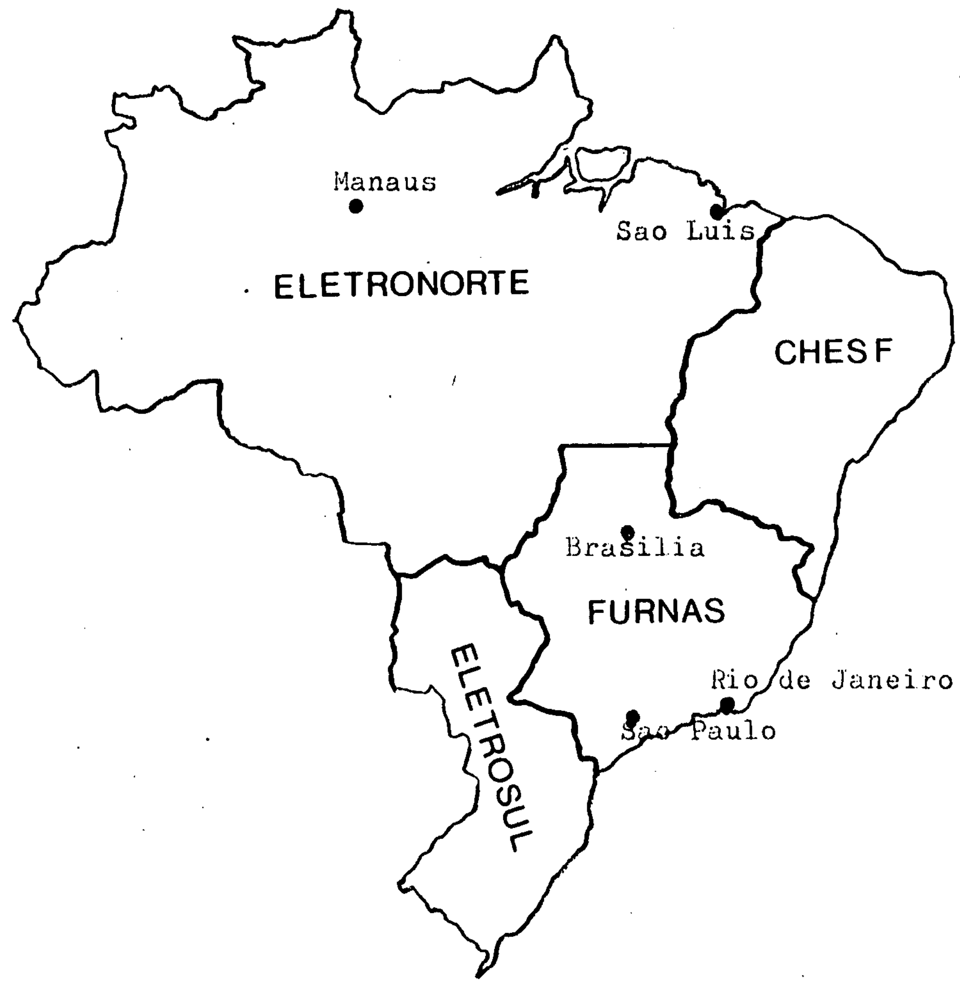
ELETROSUL was to operate in the states of Rio Grande do Sul, Santa Catarina and Paranã (the political South region). CHESF was to

Figure 4.1 : Areas of Operation of ELETROBRAS Subsidiaries, 1976



Source : Mundo Eletrico, Ano 18, no.207A, December 1976, p.114

Figure 4.2 : Redefined Areas of Operation, 1980



Source : FURNAS Boletim Informativo, Ano 8, no.70, Jan-Mar 1980, p.7.

operate in the North East region, that is the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraība, Rio Grande do Norte, Ceará, Piauī and Maranhão. The area of activity of ELETRONORTE was Pará, Amazonas, Acre, the three Federal Territories, Goiás north of latitude 15°S, and Mato Grosso north of 18°S(420).

The Centre West region had been divided between FURNAS and ELETRONORTE, but since the definition of the regions of operation, Mato Grosso has been divided into two states, Mato Grosso and Mato Grosso do Sul, using the rios Itiquira and Corrente as the boundary. As a result, in March 1980, the areas of operation were redefined. Mato Grosso do Sul came under the jurisdiction of ELETROSUL, and, in return for this loss, FURNAS gained the region of Goiás south of latitude 12°S, and in so doing gained control over the proposed hydroelectric development of UHE São Felix on the upper reaches of the rio Tocantins (see p.241). In return for losing part of Goiás, ELETRONORTE now operates in the whole of the new state of Mato Grosso(421).

It is interesting to note that the headquarters of ELETRONORTE are in Brasīlia, which is inside the concession area of FURNAS. This is, probably, a result of the combination of better communications with Brasīlia than with any major city within the concession area, and the fact that it was the furthest that qualified personnel could be persuaded to move from the South East region, where they had been previously employed.

FURNAS

Centrais Elétricas de Furnas S.A. was created in 1957 to develop the hydroelectric potential of the Furnas site on the rio Grande (see p.101). Over the years the role of the company has changed, and it is now responsible for bulk generation and transmission in the South East region of Brazil.

In 1978, the total installed capacity of the FURNAS system was 5.3 GW, which represented 37% of the total in the South East region. Work is currently in progress on UHE Itumbiara and the nuclear power station Angra I. These two power stations will add a further 5.2 GW to the total installed capacity of FURNAS, if they are successfully completed. The total length of high voltage transmission lines in this concession area was 9 150 km, 4% greater than in the previous year, but FURNAS is responsible for the D.C. transmission lines from UHE Itaipu to São Paulo. When the D.C. system is completed, some 1.000 km of transmission line will be added to the FURNAS network. From 1977 to 1978, the total installed capacity of the companies step-down substations increased by 3%, to 7.13 GVA.

The total energy supplied from FURNAS in 1978 was 27.1 TWh. This comprised 24.9 TWh produced by the system alone, with the rest being purchased from CELG, and CFLCL, and received from the systems of CELG, ESCELSA, CESP and ELETROSUL for distribution. The major utilities consuming power from the FURNAS system in 1977, were 'The Light', CPFL, CEMIG, CBEE, CELF, CEP, ESCELSA, CEMAT, CFLCL, ELETROSUL, and the construction site for Angra I. With these ten utilities, FURNAS produced 24% of the total electrical energy in Brazil in 1978.

During 1978, the company's net operational income was Cr\$ 6.6×10^9 (1978 prices), an increase of 47% over 1977, but this was within the inflation indices, as the operational costs only rose by

31.4% in the same period. Net earnings reached Cr$ 2.1×10^9 and dividends of Cr$ 1.2×10^9 were declared (1978 prices). A total disbursement of Cr$ 9.9×10^9 was made on the construction works essential for the expansion of the system, and the overall permanent assets, as of 1978, reached Cr$ 91.8×10^9 (422-424). By 1980, the situation had, however, changed and the financial situation of the company had become rather precarious. FURNAS depends for 85% of its income from ELETROBRAS, which, in 1980, following a massive devaluation of the cruzeiro in December 1979, was struggling to pay off international loans(425). Even as late as April 1980, FURNAS's budget for that year had not been finalised.

For a time, FURNAS was the most powerful of ELETROBRAS's subsidiaries. Financially, it was in the strongest position, and indirectly, it served the greatest number of customers. It was operating before the creation of ELETROBRAS, and had established a clearly defined market for its power. More recently its position has been less clear, and its role as a subsidiary not well defined. It shares the South East region with two extremely powerful state companies, CESP and CEMIG, as well as 'The Light', now owned by ELETROBRAS (see p.161). Its regional mission was, originally, to build large scale hydroelectric power stations which would require an investment too great for the local concessionaires. It was also to ensure interconnection between existing systems.

It has, to date, worked to the benefit of the South East region due to being able to achieve economies of scale. However, as FURNAS is only involved in generation and high voltage transmission, 'The Light' being responsible for the regional distribution, the company has the problem of trying to assess its market, in order to plan its expansion, without any direct consumers. Specific expansion plans are not made for FURNAS, as an entity. A regional plan is prepared, and the share of the local concessionaires is subtracted so as to determine FURNAS's share of input to the implementation of the plan.

As other concessionaires become more powerful, particularly CESP (see p.172), FURNAS is having an increasing struggle to maintain its market. The rapid expansion, accompanied by high energy demands, of the industrial markets in the states of São Paulo and Minas Gerais means that both CESP and CEMIG would be able to use all of the power from any new large power station without the need of FURNAS as an intermediary. This is the reverse of the situation which existed when FURNAS was first established. Also, there are few large projects remaining to be developed in the South East region, as most of the available hydraulic potential is now in the regions of ELETROSUL and ELETRONORTE.

The establishment of ELETROBRAS also removed one of FURNAS's primary roles, that of a planning agency. The company used to be responsible for the strategic planning of large scale hydroelectric power stations and long distance transmission lines. It had a strategic planning department, and a specific planning department which considered the feasibility studies of proposed projects. Over the years it had developed great experience in formulating planning methodologies. However, it lost its role of strategic planning to the Grupo Coordenador de Operação Interligada (GCOI) (see p.174) in 1973, and now concentrates on internal planning within the company.

From 1976, the annual planning routine involved three stages :

i. A fifteen-year long-term study of company development,

ii. Two five year tactical plans - the Plano de Grandes Obras (PGO), a system of expansion of large scale works, and the Plano Gerencial (PGE), looking at the company's own expansion, and

iii. Operational management - a one year plan on the above topic, but directly related to company investment and operations. In 1978, it was decided to drop the fifteen year plan, as it was a virtual duplicate of the ELETROBRAS fifteen year plan(Plano 95). There is, however, a problem for FURNAS, because there is very little co-operation between the two companies. ELETROBRAS does not send FURNAS any planning directives or request comments on proposals. In practice FURNAS only receives plans, such as the Plano 95, when they are published.

The FURNAS fifteen year plan was replaced by two reference documents. One, the Análise das Perspectivas de Expansão (APEX), outlines the alternatives for future expansion; it is not a plan, but a working document which is put before the board of directors. The other, the Programa para Referência de Expansão (PEX), is the basis on which plans must be made and sent to ELETROBRAS for appraisal. The tactical planning period has been reduced from five to three years(428).

The interview, which was the major source of the above information, gave the impression that there is a certain bitterness over the loss of FURNAS's co-ordinating role, to ELETROBRAS, and the reduction of the company's scope for expansion in the South East region. In 1980, a surplus of power was anticipated in the region, and this has reduced the need for the large scale power stations scheduled for construction by FURNAS in the Plano 95, as there will be no market to supply. At the time of the interview, April 1980, no marketing studies had been commenced for that year, nor had any irrevocable steps been taken on any new projects*.

CHESF

The Companhia Hidrelētrica do São Francisco (CHESF), formed in 1945 to build UHE Paulo Afonso on the rio São Francisco (see p. 99), and now operating as a subsidiary of ELETROBRAS, has responsibility for generation and bulk transmission in the North East region. In 1978, its operating income was Cr$ 2.9×10^9, with net earnings of Cr$ 0.6×10^9 and a declared dividend of Cr$ 0.4×10^9(429). It came under the control of ELETROBRAS when the latter was created, and this move gave CHESF greater financial freedom to undertake construction of new power stations and transmission lines. By 1978, the installed capacity of the company had reached 2.4 GW, and construction of UHE Paulo Afonso IV was under way, as was the controversial UHE Sobradinho, further upstream. In accordance with the Plano 95, both these power stations should now be fully operational. The sixth generating unit of UHE Sobradinho was scheduled to be installed by mid-1981, raising the total installed capacity of the station to 1.05 GW. The sixth generation unit of UHE Paulo Afonso was scheduled to be installed by the end of 1981, giving a total installed capacity of 2.46 GW.

---

* This situation, as described by FURNAS, contradicts that implied by ELETROBRAS in the Plano 95, where it was considered of primary importance that UHE Itaipu should not be more than six months behind schedule, or a power shortage would result in the South East region (see p.119).

Two other large scale schemes are scheduled to be built on the rio São Francisco. UHE Itaparica, is planned to begin operation early in 1985, and to be completed in mid-1986, with a total installed capacity of 2.5 GW (430). The other scheme is UHE Xingó, a 4.0 GW hydroelectric power station, proposed downstream of UHE Paulo Afonso. It has been in project for quite some time, and it is likely that construction will now go ahead. The Plano 95 recommends it as the most economical solution to meeting the future demand in the North East region, once transfer of power from UHE Tucuruí should cease, as forecast for 1987 (see p.253). A construction schedule was not, however, published in the Plano 95(431).

In many ways CHESF has been instrumental in aiding the development of the economically poor North East region, although the detrimental social and economic effects of UHE Sobradinho have been the subject of much controversy (432). The position of CHESF as a subsidiary of ELETROBRAS is happier than that of FURNAS, as the market to which it is the major supplier is still undergoing considerable expansion.

ELETROSUL

Centrais Elétricas do Sul do Brasil S.A. was formed by the merger of pre-existing utilities in the South region in 1968. It is responsible for supplying electricity to this characteristically rural region which has little industrial development. The overall energy consumption is low, as well as the consumption of electricity, but both are now showing a tendency to increase(433). In 1978, the total installed capacity was 1.32 GW, which was supplied by two hydroelectric power stations and four thermal power stations (the area of concession of ELETROSUL includes coal-rich Santa Catarina). For that year, its operating income was Cr\$ 2.8×10^9, with net earnings of Cr\$ 0.5×10^9. Dividends for 1978 were declared at Cr\$ 0.3×10^9 (1978 prices) (434). This was an improvement over 1974, when the net earnings were only Cr\$ 0.1×10^9 (1974 prices), and no dividends were paid.

In an energy sense, the area of operation of ELETROSUL is becoming more important. With the growing lack of available large scale hydraulic potential in the industrial South East, and the greater economic viability of long distance transmission, the rivers in the South region are now being regarded as potential suppliers of electricity to the industrial South East. UHE Itaipu is an obvious example of this, the project is owned by Itaipu Binacional (see p.162), and has little to do with the ELETROSUL system, except that an interregional link is being constructed through the Ivaipora sub-station (see p.116). Some of the power from UHE Itaipu will go to the South region, but the bulk of it will go to São Paulo city.

ELETROSUL is constructing the 1.99 GW UHE Salto Santiago and 2.5 GW UHE Foz do Areia on the rio Iguaçu, but there is a 500 kV A.C. connection from both to the UHE Itaipu-São Paulo transmission line, and most of the power from these two stations will go to São Paulo. However, with rising energy demand in the South region, ELETROSUL, in collaboration with CNEC (see p.107) has just completed a preliminary study of the upper rio Uruguaī basin, and it is planned to construct two hydroelectric power stations on that river in the immediate future(435).

ELETRONORTE

Centrais Elétricas do Norte do Brasil S.A. is the most recently formed of the four ELETROBRAS subsidiaries. Its area of operation is the largest, as it covers most of the Amazon Basin, and 50% of the national territory, a total of 4.9×10^6 km^2. Unlike the other subsidiaries, ELETRONORTE has no installed generating capacity which it has constructed. It is responsible, however, for the transmission lines and sub-stations for the existing power stations in the Amazon region(436). In 1980, the total installed capacity of the region of operation of ELETRONORTE was expected to be approximately 600 MW(437), but each installation, by virtue of its isolation was operating independently. The current estimate of hydraulic potential in this region is 92 GW (see p.41) and, as the hydraulic potential in the rest of Brazil becomes exhausted, the importance of ELETRONORTE as an enterprise in the Brazilian electrical power industry will increase.

ELETRONORTE was originally created by law no.5824, in November 1972, in order to develop and build the 3.96 GW UHE Tucuruī(438). The company will also be responsible for the construction of the other hydroelectric power stations in the Tocantins cascade (see app.4). It is to continue the systematic study of the hydraulic potential of the Amazon tributaries which was initiated by the Comitê Coordenador dos Estudos Energéticos da Amazônia (ENERAM)(439). The company is also conducting preliminary surveys of the rio Xingu. The estimated potential of this river is very high, but the idea of its exploitation is controversial because of its possible effects onthe large numbers of Amerindians who live along its banks (see p.228) (440).

Due to the isolated nature of all of the sites in Amazônia, the hostile terrain and climate, and the lack of communications infrastructure, much of the work of ELETRONORTE has to be innovative and pioneering. The market for electrical energy is, at the moment, domestic and commercial, but it is hoped that as the installed capacity increases industry will be attracted to the region.

Financially, ELETRONORTE is dependent upon ELETROBRAS. In 1978, ELETRONORTE's reported assets were Cr\$ 12.2×10^9, and its net earnings were Cr\$ 0.2×10^9 (441). However, the ambitious Tucuruí project is suffering from rapidly escalating costs. The financial strain on ELETRONORTE is being lessened, however, by the injection of funds into the scheme by the Government, at the expense of other national projects, with the exception of UHE Itaipu.

'The Light'

'The Light' has been operating in Brazil since 1899. It is a distribution company operating in both the states of São Paulo and Rio de Janeiro. Originally it was involved in generation as well, but the problems of the 1950s (see p.120), coupled with increasing anti-foreign feeling in Brazil, led to an unofficial agreement that 'The Light' would restrict itself to distribution. As a result, it purchases 75-80% of its power from FURNAS and CESP.

Until 1979, 'The Light' was owned by Brascan Ltd. of Canada. Originally, the Canadian enterprise owned nine companies in Brazil - 'Rio Light', 'São Paulo Light', Companhia Fluminense and six small companies in the state of São Paulo. These were all amalgamated in 1967 to form the company Light - Serviços de Eletricidade S.A., which retained the common name of 'The Light'(442). At that time it was the last remaining major foreign controlled utility in Brazil, but early in 1979, the Brazilian Government purchased the 83% holding of Brascan for US\$ $380x10^6$ (December 1978 prices), of which US\$ $210x10^6$ was paid on completion of the deal, and the remainder followed 90 days later.

The deal was expected to result in a book loss of US\$ $466x10^6$ for Brascan, but unlike some other takeovers by the Brazilian Government, Brascan is being allowed to reinvest in Brazil if it so wishes(443). The Minister of the MME, at the time, Shigeaki Ueki, maintained that one of the motives for the purchase of the company was that the quality of 'The Light's' services had markedly deteriorated as a result of the company's inadequate investment in the electrical power industry. This problem has been the subject of a long standing argument since the 1950s(444). The bulk of 'The Light's' investment had been in routine maintenance with little investment in new plant. The response of Brascan to this was given at the annual shareholders meeting in Toronto, where Brascan claimed that it had invested US\$ $1.5x10^9$ in 'The Light' with the result that 70% of the company's plant was less than ten years old. In 1977, 'The Light's' capital programme totalled US\$ $285x10^6$, an increase of 10% over 1976(445,446). It should be noted, that, during the period when Brascan owned the company, dividends were paid half yearly to the shareholders, but in the first half of 1979, after the takeover, no dividends were paid and the money was reinvested(447).

Despite the demand for electricity increasing at a rate of 10% per year in the region of concession of 'The Light', the company is obliged to purchase its power from FURNAS and CESP at rates set by the Federal Government. This means that any increase in output does not flow through to earnings, and 'The Light' had had to become increasingly dependent upon the relatively short term funds available on the international capital markets, where, in 1978, repayments on loans rose by a factor of three(448).

'The Light' does possess its own generating plant, principally UHE Ilha das Pombos, UHE Fontes and UHE Nilo Peçanha, all in the state of Rio de Janeiro, however, because of the compulsory purchase of power from FURNAS and CESP, these plants rarely run at full capacity(449). In 1978, 'The Light' generated 819.4 MWav, 7.8% less than in 1977, yet it purchased 3.9 GWav, an increase of 12.6% over the previous year(450).

Itaipu Binacional

Itaipu Binacional was created in accordance with article 3 of the Tratado de Itaipu, signed by the governments of Brazil and Paraguay on 26 April 1973. The binational entity is made up of members of ELETROBRAS, and its Paraguayan equivalent Administración Nacional de Electricidad (ANDE). This arrangement is for an indeterminate period of time, and the company has offices in Brasília and Assunción.

The initial objective of Itaipu Binacional was to develop the hydraulic resources of the rio Paraná, from, and including, the Salto Grande de Sete Quedas up to the Foz do rio Iguaçu. The company was given the judicial, financial and administrative capacity, as well as the technical responsibility, to study, plan, direct and execute the works which constitute its objective.

At the highest level, the administrative organs of Itaipu

Binacional are the Conselho de Administração and the Diretoria Executiva, (Administration Council and Executive Directorate). The Conselho de Administração has twelve members, six nominated by the Brazilian Government (of which, one will be chosen by the Ministério das Relações Exteriores, and two by ELETROBRAS), and six nominated by the Paraguayan Government (again one chosen by the Ministério das Relações Exteriores, and two by ANDE). The Conselho is managed by a non-voting Director General and Assistant Director General. The term of office of each councillor is four years, but renomination is possible.

The Diretoria Executiva is the organ responsible for the day to day practical administration. It comprises an equal number of nationals from both countries, with a Director General, and technical, judicial, administrative, financial and co-ordinating directors. Their term of office is five years, and, again, they can be renominated. The directors and assistant directors are nominated by the Governments of the two countries, after recommendations put forward by ELETROBRAS and ANDE. The Director General of the Conselho de Administração is responsible for the direction, organization and co-ordination of the activities of Itaipu Binacional. It also falls to him to direct and co-ordinate the work of the Diretoria Executivo, and to supervise and co-ordinate the planning and execution of different areas of activity.

In the city of Foz do Iguaçu, the representative of the Director General has, as a principal function, the role of arranging social integration of the Itaipu enterprise with the city and surrounding regions. The Diretoria Executivo has to implement the orders of the Tratado de Itaipu as well as the decisions of the Conselho de

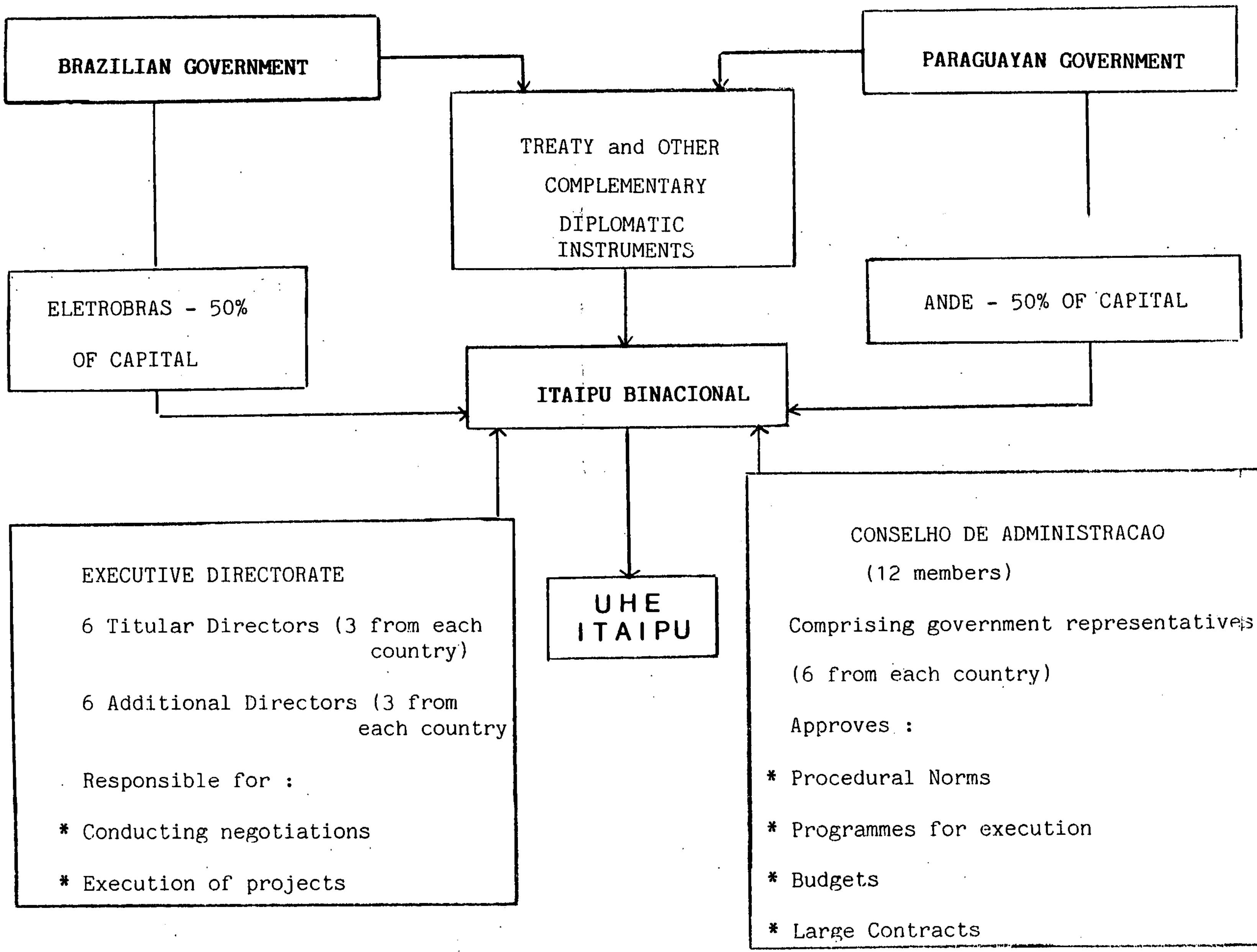
Administração(451), (see figure 4.3). To date, the role of Itaipu Binacinal has been the construction of UHE Itaipu. The enterprise is responsible for the financing of the project, the selection of consultants, awarding of contracts and general co-ordination. It was formally inaugurated at a ceremony held at the border between Brazil and Paraguay, on 17 May 1974, in the presence of the two presidents, Ernesto Geisel and Alfred Stroessner(452).

It is interesting to note, that the project was originally conceived under the government of Emīlio Garrastazu Mēdici, this Brazilian president actually signing the Tratado(453). It is perhaps the largest project that will ever be undertaken by a Brazilian Government, and is a symbol of the Mēdici Government, which initiated a number of large projects during the years of the "economic miracle", including the construction of the Transamazônica Highway.

CEPEL

The Centro de Pesquisas de Energia Elētrica was created by ELETROBRAS for the development of technology applicable to electrical systems and equipment(454). The full entry of Brazil into the development of systems for generation, transmission and distribution of electricity stemmed from the change from importation of equipment to the manufacture of this equipment in Brazil by subsidiaries of foreign manufacturers. However, the concessionaires, preoccupied with the problems of the rapid expansion which occurred in the power industry after the Second World War, had neither the time nor resources to study the technical questions which were only indirectly connected to their immediate concerns. Technical difficulties were

Figure 4.3 : Itaipu Binacional - Structure and Function



solved as they arose, frequently with the aid of foreign consultants.

The need for more formal research became more pressing during the 1960s, when Brazil began to build power stations on a much larger scale and prepare long term plans. At that time, some university departments had small units undertaking electro-mechanical research. The concessionaires also formed their own study departments and small laboratories, with the principal aim of improving maintenance of the protection and measurement instruments and equipment. Most of the research, however, was geared to solving immediate small scale problems. At the same time as long-term problems were growing, so was the interest in the establishment of a formal research organization(455).

In June 1971, the MME stated the intention of creating a research centre, on the campus of the Federal University of Rio de Janeiro, and in December of that year, ELETROBRAS was authorised to set up a Fundo de Desenvolvimento Tecnológico (Technological Development Fund), with the objective of financing scientific and technological development initiatives of interest to the Brazilian electrical power industry.

The initial studies for the creation of a research centre were given to FURNAS, which then made a consultation contract with the Canadian Institut de Recherche de l'Hydro-Québec (IRFQ), in order to define the basic concept behind such a project. As a result, CEPEL was created in March 1974, directly subordinate to ELETROBRAS, and responsible to the four ELETROBRAS subsidiaries(456). The basic objective of CEPEL was defined in law as :

"...to provide an infrastructure for scientific research, and to seek for the development in the country of an advanced technology in the field of electrical equipment and systems".

As fundamentals of this objective, five medium and long term objectives were established :

i. to integrate CEPEL into the national electrical power industry,

ii. to establish Systems and Electrical Equipment Laboratories,

iii. to back up the requirements of the industry,

iv. to shape their own human resources and those of the electrical power industry, and

v. to integrate CEPEL into the scientific community.

In the first five years of its existence CEPEL acted jointly, with ELETROBRAS and its subsidiaries and some state companies, in the fields of supervision and control of electrical systems, isolating materials, corrosion, project optimization for transmission lines, as well as its own chosen areas of research(457).

Two laboratories have been established. The Laboratōrio de Sistemas Elētricas (LSE), on the campus of the Federal University in Rio de Janeiro, and the Laboratōrio de Equipamentos Elētricos (LEE), in the town of Adrianōpolis, Rio de Janeiro state, and sited close to the 500 kV substation of FURNAS. The LSE began operation in its new headquarters in 1979, and the LEE had been expected to commence operation at around the same time. However, it was still under construction during 1980. With the progressive conclusion of works on the two laboratories, the scope of CEPEL's research has gradually expanded, and in 1978 the centre prepared its first three year plan (1978-1980) which was subsequently approved(458).

Some of the research being undertaken by CEPEL will have a significant effect on Brazil's future energy planning. One of the roles of the systems and materials department at LSE is the optimization of energy planning (see p.219), and in 1977 two research programmes were set up on the supervision and control of electrical systems. One is the elaboration of a remote programmable terminal for the acquisition of data, and the other is the development of a methodology and algorithms for the implementation of advanced mathematical functions in control systems. A prototype of the first programme was installed in one of FURNAS's substations which is under the direct control of the Sistema de Supervisão e Aquisição de Dados do Centro de Controle do Sistema de FURNAS, (System for supervision and acquisition of data for the control centre of the FURNAS system). Preliminary results suggest that a plan of collaboration should be established between CEPEL and FURNAS with the aim of developing a prototype for a regional system of supervision and acquisition of data based on microprocessors(459).

CEPEL is funded by ELETROBRAS, which invested Cr$ 250x10^6 (1978 prices) into the company in 1978(460). As well as this Federally sponsored company, oriented towards national progress in the fields of science and technology, as applied to the electrical energy services(461), there are two major state enterprises which play an important role in the Brazilian electrical power industry. They are CEMIG and CESP, and they wield much power within the industry.

CEMIG

Centrais Elétricas de Minas Gerais is indirectly responsible for much of the outlook of the present day electrical power industry in Brazil. It has been the training ground for many of the top men in the various state utilities, especially FURNAS. Some of these have also moved on to Itaipu Binacional. It was CEMIG which discovered the Furnas site, but realising that the scope of its resources was insufficient to develop this promissing site, the company pressed for its development nationally, and thus began the gradual integration of the region and then the country as an electrical entity.

Founded in 1952, CEMIG was the first mixed economy state company to be created in Brazil in order to fulfill an overall electrification plan. In its initial programme it installed 150 MW of generating capacity, and the associated transmission system. This was the largest works programme to have been attempted at that time in Brazil. However, as its resources for large scale capital programmes were not large, the increase of CEMIG's installed capacity was slow during the 1960s. More recently, however, CEMIG has entered the world of large scale hydroelectric power station construction, and in 1978, UHE São Simão was inaugurated on the rio Paranaíba. When all phases are complete it will be Brazil's fourth largest hydroelectric power station, with a total installed capacity of 2.7 GW. If the last generator was installed according to schedule at the end of 1979(462), it will in fact be the second largest currently operating in Brazil (after CESP's UHE Ilha Solteira 3.2 GW). In 1978, the estimated final cost of UHE São Simão was US$ 1.0×10^9 (August 1978 prices), and initially the power will be used to meet the demand in the industrial South East, as opposed to Minas Gerais state alone, which at present has sufficient installed capacity to meet its current needs(463).

In the case of UHE Emboração, which CEMIG is building, also on the rio Paranaîba, with the help of an Inter-American Development Bank (IADB) loan of US$ $70x10^6$ (1977 prices), this 1.0 GW hydroelectric power station will supply the market of Belo Horizonte. The power is expected to help establish new industries, and create 60 000 new jobs in the state of Minas Gerais. The loan from the IDB covers 9.5% of the total estimated project cost, and CEMIG itself will be responsible for 45.7% and ELETROBRAS a further 33.3%. Included in the project is the modernization of CEMIG's supervision and monitoring network(464).

This extensive Federal Government participation in the projects of CEMIG represents a new direction for the company. It has become necessary because of the enormous funds required for many of the current hydroelectric projects, and it is possible that the company may lose some of its autonomy if this financial dependence upon ELETROBRAS is maintained. Throughout its existence, CEMIG has developed an intense, increasing and uninterrupted programme of works, which has been fulfilled by up-to-date techniques, with a constant endeavour to keep costs to the lowest feasible. The company has contributed decisively to the increase of the state economy.

Its motto is :

"Fazendo o progresso com energia"*

and in the opinion of the journal Mundo Elétrico, CEMIG has surpassed the frontiers of an electricity enterprise by establishing itself as

* Making progress with energy.

a development agency(465).

CESP

Centrais Elêtricas de São Paulo was founded in 1966 by the amalgamation of eleven concessionary electrical power companies, and the takeover, in 1975, of the controlling interest in CPFL, which had a concession area of 212 000 km^2. Most of the company's consumers are in the state of São Paulo, with a small percentage in Mato Grosso do Sul and Minas Gerais. The concession area includes extremely poor and backward regions of São Paulo state, but also the extremely important industrial centres such as Campinas and São Paulo city. For this reason CESP wields considerable power in the Brazilian electrical power industry.

In 1979, the company had assets of Cr$ 134×10^9, of which 90% was invested in property connected to the production, transmission and distribution of electricity(466). Since 1969, CESP has been involved in an ambitious programme of expansion, and has increased its installed capacity from 1.3 GW to 8.3 GW in 1979, representing a total increase of 515%. This corresponds to an average yearly increase of 19.9%. Production of electricity rose from 3.0 TWh in 1969 to 35.5 TWh in 1979, an increase of nearly a factor of 12(467). (Compared to the increase in production for the whole of Brazil, over a ten year period, this is extremely high. 1968 production of electricity in Brazil was 38.1 TWh and this had risen to 111.1 TWh in 1978, a factor of increase of just less than 3).

In that period, CESP constructed three large hydroelectric power stations, UHE Jupia on the rio Paranã (1.4 GW)(1969), UHE Ilha Solteira (3.2 GW)(1973), on the same river, and UHE Agua Vermelha on the rio Grande (1.4 GW)(1978). In addition to a number of small schemes, CESP is in the process of constructing the 1.8 GW UHE Porto Primavera on the rio Paranã(468,469). According to the Plano 95, the station will start operating in 1985, but its total installed capacity is given as 1.1 GW(470).

When the statistics are studied, it becomes apparent why FURNAS is concerned with its potential loss of market. Not only are CEMIG and CESP (principally the latter) constructing hydroelectric power stations with capacities of greater than 1.0 GW, their shares of the regional and Brazilian markets are rising whilst that of FURNAS is falling, as shown in Table IV.ii.

Table IV.ii : % Participation in Energy Production

	1978		1979	
	S.E.Region	Brazil	S.E.Region	Brazil
FURNAS	31.5	22.4	25.7	28.0
CESP	38.9	27.7	40.6	17.7
CEMIG	14.2	10.1	19.0	13.1

Source : Relatõrio Tẽcnico 1979

Note : CESP is the greatest single producer of electricity in Brazil.

In accordance with the Lei de Itaipu (see page 173), FURNAS and ELETROSUL will have to make contracts with Itaipu Binacional for purchase of all the power from UHE Itaipu, in proportion to their respective markets, for the next twenty years. In turn FURNAS and ELETROSUL will have to make contracts with the state companies, by which these companies guarantee to buy this power for the same period(471). This theoretically shifts the responsibility of use of the UHE Itaipu power to the state companies. A number, however, notably CESP, have not slowed down their ambitious construction programmes, and there is a real danger of there being an excess capacity. CESP has been strongly opposed to the Itaipu law, and if it is changed in favour of the state companies FURNAS could have serious problems selling the power(472). The law was in fact revoked in 1980, and the concession areas of the ELETROBRAS subsidiaries altered, but there is no information available on any changes in purchasing of the power(473).

Internal Structure of ELETROBRAS

Following the Tratado do Itaipu signed by Brazil and Paraguay, on 26 April 1973, the lei de Itaipu, no.5899, was passed by the Brazilian Government to define the use of the energy from UHE Itaipu. As well as accomplishing this, the law also defined the subsidiaries of ELETROBRAS, and their areas of concession, and redefined ELETROBRAS's internal structure.

UHE Itaipu is to supply power to the South East and South regions, and the operational co-ordination of these regions was declared to be under the jurisdiction of the Grupo Coordenador de Operação Interligada (GCOI), and integrated through representatives of ELETROBRAS and the concessionaïres(474). Law no.5899 was followed by Federal decree no.73102, of 7 November 1974, which defined the methods of application of the rules and recommendations in the lei de Itaipu. The decree has references on how to minimise operation costs, maximise hydroelectric generation, and the minimum allowable level of reliability. In accordance with this decree, GCOI must present an annual operation plan (Plano de Operação)(475).

GCOI

This is, essentially, a power council, comprising various state companies and the ELETROBRAS subsidiaries. Originally, CHESF and ELETRONORTE were excluded, but CHESF is now part of the council because its installations on the rio São Francisco experience the regulatory effect of CEMIG's UHE Três Marias, which is situated upstream. ELETRONORTE is not included because, as yet, it has no significant transmission system. With the creation of GCOI, the South and South East regions became more strongly electrically connected.

The structure of GCOI is similar to that of the Diretoria de Operações of ELETROBRAS, the activities of the two are often parallel, and frequently overlap, but they are legally quite separate.

For the overall structure of GCOI, see Figure 4.3.

Conselho de Deliberativo

The presidents of the various companies involved meet at this council. It serves no official function, and wields no power.

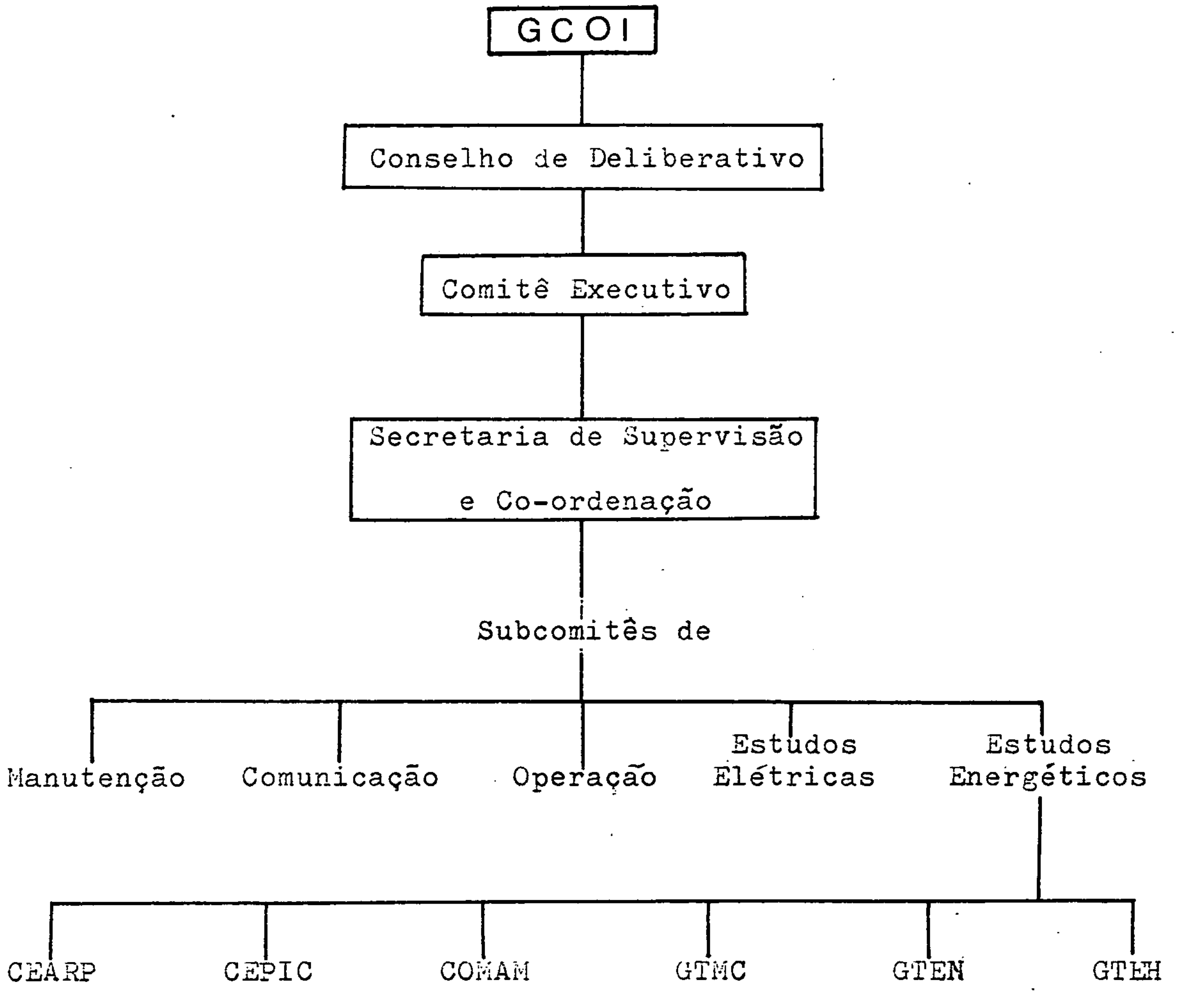
Comitê Executivo

This comprises the Operations Directors of all the participating companies. It is presided over by the Director of ELETROBRAS's Diretoria de Operações and it meets regularly at three monthly intervals.

Secretária de Supervisão e Coordenação

The head of this has the same status as an ELETROBRAS director. The Secretária operates within ELETROBRAS. It controls the Conta de Consumo de Combustiveis (CCC, the account for the consumption of

Figure 4.4 : The Operating Structure of GCOI



Source : GCOI Sudeste/Sul, Subcomitê de Estudos Energéticos,
Plano de Operação para 1980.

fuels). All the companies affiliated to GCOI pay a sum into the CCC, and those companies which are operating thermal power stations receive a subsidy from the CCC to pay for the cost of the fuel. This is one of the aspects of interconnected operation which has arisen. The profits of each company vary widely, and this measure is an attempt to ensure that there is no cost differential between the electricity in each region. The national policy is to work towards regularising the cost of electricity throughout Brazil. At present, the tariffs in the North East and North are being held at an artificially low level, in order to try and stimulate industry.

The Secretária prepares weekly, monthly and annual reports on the operation of the Brazilian electrical power systems. The operation data is collected, and used to identify deviations from the planned schedule. However, the Secretária does not analyse these deviations, it just compiles the data, and produces a computer printed report. Its role is in the process of changing. In 1979, it founded the National Control System (presumably Sistema de Controle Nacional), and the role of the Secretária is the short term supervision and co-ordination of this System. It is slowly developing the attributes of the National Control System, and once this has been established it will take over the role of the Sub-comitê de Estudos Energéticos (see p.177). and the role of the Sub-comitê de Operação (see p.177) will be taken over by the Secretária.

The Comitê Executivo makes the decisions for GCOI, and the Secretária is the organ currently responsible for their implementation.

Sub-comitê de Manutenção

This subcommittee prepares the operation and maintenance schedules for the power stations. It studies the performance of the various power stations, and prepares the reliability indices.

Sub-comitê de Comunicação

This deals with communications between the different companies which are interconnected, either directly by transmission facilities, or indirectly by power purchasing agreements. It develops the communications network from the power stations, with the use of microwave and telephone links.

Sub-comitê de Operação

This is involved with short term operation problems. It discusses the use of reserve power, and the criteria for its use. It schedules the interchange of electricity between companies.

Sub-comitê de Estudos Elétricos

This and the Sub-comitê de Estudos Energéticos are the most important of the subcommittees. This one does the electrical studies in order to verify the medium term planning - the monthly, tri-monthly, and yearly plans. It studies load flow, stability, load schedule and makes short circuit studies. It defines the electrical constraints on the systems as well as the limits of energy interchange between companies at peak times.

Sub-comitê de Estudos Energéticos

This subcommittee is co-ordinated by the Departamento do

Operação Energética (DEOP) of ELETROBRAS, and almost all the work of the latter is done in relation to this sub-committee, which operates through three commissions and three work groups.

CEARP

The Comissão de Estudos e Acompanhamento do rio Paraība (CEARP) was set up to study the operation and use of the rio Paraība. It is one of the river systems in Brazil, that has been developed for multiple use, and it, therefore, requires operation co-ordination. It is an important river for the city of Rio de Janeiro, as it is used for power, drinking water, navigation and effluent disposal. Operation of hydroelectric power stations on this river is constrained by the need of the use of the river for water supply and navigation(476). (This is the only example of the multiple use of a Brazilian river where electricity production was not the principal concern).

CEPIC

The Comissão de Estudos de Programação de Intercâmbios e sua Contablização (Commission for the study of planning for exchange and accounts) was created as an impartial body to ensure that some companies do not gain financially at the expense of others. It determines the regulations for energy exchange between companies and arranges the accounts. (The money changes hands on paper, not in reality) It is involved with all of the exchanges which occur between companies, not just the energy exchanges. It acts as co-ordinator between companies which are not even electrically interconnected. It defines the criteria to maximise electricity production at minimum cost and arranges the substitution of thermal power by hydroelectric power between companies.

COMAM

The Comissão de Analise do Mercado (COMAM) was created to forecast the market demand. It monitors the performance of the forecast to verify the values used. It studies the growth behaviour of the market. The actual studies for load forecasts are made by DNAEE, therefore, the load forecasts made by COMAM have to be approved by DNAEE. Once a year, COMAM prepares a five year market forecast which is presented to GTEN for consideration.

GTMC

The objective of the Grupo de Trabalho de Metodologia e Critérios (GTMC, work group on methodology and criteria), is to develop a methodology and criteria using mathematical models and computer programmes. It is developing a system of programmes matched to the national control system of ELETROBRAS being developed in Brasília. Sophisticated methods and programmes are being employed to plan operations, and the Brazilian electrical power system will itself be more sophisticated once UHE Itaipu and the nuclear power station Angra I begin operation. This work group develops and discusses the methodology behind the models required.

GTEN

The Grupo de Trabalho de Estudos Energéticos (GTEN, work group on energy studies) uses the models and methodology of GTMC to produce the energy operation plans for one month, three month and one year periods. It also makes studies of the expected behaviour of the systems over the next five years. Every three months the medium term plan is reviewed. Computer simulations of reservoir levels are made, and the generation levels of all the power stations are forecast. In any three month period, GTEN can forecast the most important operation values for the next three months, taking into account the load forecast, and the reservoir inflow estimate using statistical simulation. In the South East region, an hourly despatch is received from each large scale hydroelectric power station, and the operation and maintenance schedules can be revised, depending on the water flows at the time of the bulletin.

Normally GTEN meets with the GCOI companies monthly to review the situation. Only in critical periods, when the behaviour of the system departs from the forecast, is the frequency of the review increased. One of the other roles of GTEN is to monitor the day by day operations of all stations. Information is sent by telephone or telex, and this acts as an important feedback on all the planning processes.

GTEH

The Grupo de Trabalhos de Estudos Hidrologicos (GTEH, work group for hydrological studies) was set up after a disaster when UHE Euclides da Cunha and UHE Armando Salles de Oliveira, both on the rio Pardo, were overtopped and subsequently breached in January 1977. This resulted in the destruction of 4 000 homes and the two hydroelectric power stations. Although much of the data was destroyed, it was estimated that the area suffered a 10 000 year flood(477). Naturally there was much public concern that this kind of disaster should be prevented, therefore the role of GTEH is to ensure the safety of the peoples and lands downstream of such large dams.

It defines the discharge limits from the hydroelectric power stations, using the available hydrological data, in order to minimise any adverse effects upon agriculture, fishing and navigation. It makes all the studies related to hydrology - the inflow data for the energy studies are prepared by GTEH.

The differences between the work groups and the commissions is that the former are permanent, but the commissions may only be temporary. The Comitê Executivo and the subcommittees prepare the guidelines upon which the work groups and commissions operate. Reports prepared at subcommittee level and above are published. The Plano de Operação, three monthly and annual is published by SCEN(478).

ELETROBRAS - Planning

The scope of ELETROBRAS is much wider than that of GCOI, as it is involved with the overall development of the electrical power industry, not just the co-ordination of the different enterprises within it. However, much of the work of the two does overlap, although the contact between the two is usually only through the various subcommittees, work groups and commissions, which are headed by ELETROBRAS personnel.

It appears that there is very little inter-departmental communication within ELETROBRAS. In Rio de Janeiro, the company is spatially separated into three buildings, in different streets, and there is another office in Brasília.

There are five other directors working on the board of the company, in addition to the Director of ELETROBRAS. They are the directors of the Diretoria de Integração Regional, the Diretoria de Financiamento e Economia, the Diretoria de Operação, the Diretoria de Planejamento e Engenharia and the Diretoria de Coordenação(479). Involved directly with planning are the Diretorias de Operação and Planejamento e Engenharia. The Diretoria de Operação is closely paralleled by GCOI, and the director co-ordinates the Comitê Executivo of GCOI. Within the Diretoria de Operação is the Departamento de Operação Energêtico (DEOP), the head of which co-ordinates the Sub-comitê de Estudos Energêticos. There are three divisions within the DEOP. The Divisão de Operação Energêtico (DVON), which prepares the energy studies for operation planning. The chief of DVON co-ordinates GTEN; the Divisão de Engenharia de Operação (DVEO), whose chief co-ordinates GTMC, and the marketing division, which does marketing studies. Its chief is co-ordinator of COMAM, and the work of the two is almost the same(480).

There are four departments within the Diretoria de Planejamento e Engenharia. The Departamento de Estudos Energêticos (DENE) is concerned with computer modelling, and presentation of data, and long term programming for expansion. The Departamento de Sistemas Elêtricas, the Departamento de Geração and the Departamento de Estudos de Mercado (DEME). DEME prepares the market studies to predict the national energy consumption. It acts as a consultant to the other Brazilian energy utilities. It makes demographic and economic studies for the market projects, in order to make 30 year predictions of population, numbers of households, and income. This is because IBGE only make ten year projections, and ELETROBRAS produces a fifteen plan with a thirty year horizon(481). DEME produces the economic references used by the other departments in their planning(482).

Within ELETROBRAS there are a number of other departments, including the Departamento do Meio Ambiente (the Environment) and the Departamento de Eletrificação Rural, but none of these are directly concerned with planning. With the help of its four departments, the Diretoria de Planejamento e Engenharia is responsible for the preparation and publication of the 15 year plans, such as the Plano 95.

CHAPTER 5

Planning

Until 1965, public power in Brazil had been developed by a number of separate power utilities, some owned privately and others by mixed capital companies with predominantly Federal or State Government control. Some of the companies were fully integrated and provided a complete service, from generation of electricity through to distribution to the ultimate consumer. Others were primarily distribution companies, or changing their role to become so, e.g. 'The Light' (483). Since the commissioning of the FURNAS plant, in 1963, some utilities became primarily bulk suppliers, confining their activities to electricity generation and transmission(484). Each power concessionaire had developed its own independent transmission system, although, in some cases, there was incidental interconnection with neighbours. By the end of 1965, the total installed capacity in the industrial South East Region of Brazil was 5.086 GW and the market requirement at that time was 4.096 GW, giving an apparent surplus of 990 MW(485).

It was not easy for the various concessionaires to work together. Some were state companies, some were foreign. They all had different primary objectives and financial resources. In terms of quality, some outranked others, e.g. FURNAS and CEMIG were successful, whereas CHEVAP was a conspicuous failure(486).

CANAMBRA

It was into this unstructured system, that Canambra Engineering

Consultants Ltd. (CANAMBRA), a consortium comprising Montreal Engineering Company Ltd. of Montreal, Canada; Gibbs and Hill Inc. of New York, USA; and G.E.Crippen and Associates Ltd. of Vancouver, Canada(487), was invited to make a survey of hydroelectric resources in South Central and South Brazil. In addition, using information gathered on both conventional and nuclear sources of thermal power, CANAMBRA prepared a programme of power station and transmission line construction in order to supply the power markets in those regions until 1980(488). It was to be the first long term, and wide ranging plan in the electrical power industry, ever to be considered in Brazil.

Guidelines for the studies for the South Central Region of Brazil, divided into several sections, were described under the Terms of Reference for the "Power Study of South Central Brazil" dated 10 April 1962, issued by the International Bank for Reconstruction and Development (IBRD, the World Bank). A survey of hydroelectric resources in the state of Minas Gerais, and parts of the Paranaîba Basin in south-eastern Goiâs, including a feasibility study of selected sites, was to be carried out by CANAMBRA in collaboration with CEMIG, according to an agreement between the two organizations, dated 2 November 1962.

The second part of the project, designated part B of the "Power Study of South Central Brazil" was carried out under the contract for Consulting Engineering Services between FURNAS and CANAMBRA, signed on 3 June 1963. This was made up of three principal components. Part B-1, completed early in 1964, led to an interim report for power developments in the region for the four-year period 1963 to 1966. The São Paulo study consisted of a survey of the hydroelectric resources in the States of São Paulo, Rio de Janeiro, northern Paraná and eastern Mato Grosso, again with feasibility studies of selected sites. The Rio de Janeiro study was a market study and economic development programme for power generation and transmission facilities in South Central Brazil. This was later extended, in 1965, to include a study of power supplies from hydroelectric power sites, which had been previously studied, on the coastal slope of the states of Paraná and Santa Catarina, and also thermal power development using coal from deposits in Santa Catarina(489-491).

The "Power Study of South Brazil" was authorised by the Plan of Operation Agreement (PLANOP)(492), which was signed by representatives of the Government of Brazil, the United Nations Development Programme (UNDP) and the World Bank, in Rio de Janeiro, on 7 August 1967. The contract for the South Brazil study, made possible by the PLANOP agreement, was signed in Washington, D.C. by representatives of CANAMBRA and COPEL the latter acting on authority delegated by ELETROBRAS, which was the authorized agent of ENERSUL, the name finally adopted by the Steering Committee(493).

The Power Study of South Brazil included:

i. an evaluation of electrical power sites, in order to prepare an interim report for a development programme to meet market requirements until 1972,

ii. an inventory of hydraulic power sites in South Brazil,

iii. feasibility studies of selected sites,

iv. assistance in reorganization of regional hydrometric services,

v. a power market forecast to 1980, and a corresponding generation and transmission programme,

vi. a general survey of subtransmission and distribution requirements, and

vii. an evaluation of frequency conversion requirements in order to connect the state of Rio Grande do Sul with the rest of the South Region.

The initial request for this estimated three years study, at a projected cost of US\$ $3x10^6$ (1964 prices), was refused by UNDP, which, instead, offered extra funds of US\$ $0.2x10^6$ to the Rio de Janeiro Study for the Paranã and Santa Catarina evaluations. However, after visits from World Bank and United Nations representatives, the UNDP, finally, in January 1966, approved a grant of US\$ 470 400 for a less detailed study of South Brazil. The Brazilians themselves, were to contribute an equivalent of US\$ $1.4x10^6$, and the study was planned to take one and a half years. On reflection, it was considered that the sums and time allocated were insufficient, and, after a detailed review, agreement was reached in June 1966, by which the grant was increased to US\$ 700 000 and the time scale to two years(494).

The difficulties experienced by the South Region in obtaining funding for the project strongly reflect the attitudes towards Brazilian development. The South Central Region (or South East), containing the two large industrial cities of Rio de Janeiro and São Paulo, was a rich and powerful area in which it was in many people's interest to encourage industrial development. This region was an area on which the Development Banks and lending agencies could easily focus, through economically powerful individuals, all the major companies, and the Federal Government. The South Region had none of these natural advantages. It was relatively unpopulated, with little industry, and, although, the rio Paranã has subsequently been regarded as a source of hydraulic power, it is not for the South but for the industrial South East, which is to receive the power from UHE Itaipu(495).

Much of the work performed by CANAMBRA was as a supplier of specialist consultants, e.g. at the offices in Curitiba, headquarters of the South Brazil Survey, CANAMBRA supplied a study director, project manager, reconnaissance engineer, hydrologist, geologist, market analyst, power supply engineer, transmission engineer and two design and estimating engineers, and in addition, five visiting specialists—a power planning engineer, financial analyst, thermal power engineer and two transmission engineers.

Surveys - inventory studies.

The purpose of the inventory (assessment) studies was to tabulate the potential hydroelectric sites, their physical characteristics, and the power and cost characteristics of possible developments at these sites, in order to identify appropriate schemes of river development for power, and also to establish a preliminary classification of economic priority. The information was tabulated to show the reference data, physical characteristics and power and cost data on a "first-added" basis*, and to show how the power and cost data would be modified by full development of the river. Charges and

* The terminology adopted by CANAMBRA when referring to the cascade development of a river for power, used the term "first-added" to denote a hydroelectric power station which was the first of such a development scheme, and was financially and hydrologically independent.

credits between power and storage projects were distributed in an attempt to provide a balanced estimate of costs(496). In the inventory studies, the primary energy potential of a project was computed as the maximum continuous output which could be maintained during a repetition of the driest recorded period of stream flow(497). The most important information from these studies was this preliminary estimate of the firm energy and the index of its cost. The main criterion for selection of a site was on economic grounds.

The initial stage of the process was the river basin hydraulic resources survey, after this, a preliminary appraisal was made, which consisted of the application of a simplified estimating procedure to the available site information. Those sites which showed no likelihood of meeting the minimum requirements on cost were discarded. After this appraisal, more detailed estimating procedures were applied to selected sites after the completion of field reconnaissance and office studies.

In the schedule of estimated capital expenditures, the average capital cost of hydro and oil-fired steam plants planned to start prior to 1980, for commissioning after that year was US$ 150/kW (498). Of the projects studied in the South Central Region the most expensive was estimated at US$ 437/kW and the lowest at US$ 124/kW (499), On projects shown to be attractive from the inventory study, a feasibility study cost estimate was made on the completion of more detailed site investigations and design studies.

The inventory studies generally comprised:

- river profiles and maps, at various scales, as available from other agencies, and also prepared and revised by the Group's aerophotogrammetry section,

- site cross-sections and check level runs by CANAMBRA's survey section,

- surface reconnaissance of foundation conditions and borrow materials by the CANAMBRA geologist. Some previous sub-surface explorations by other agencies were also available, and

- regulated flows, design floods and tailwater curves derived from the hydrologic studies executed(500).

The reconnaissance survey of hydraulic resources in the South Central Region took nearly two years, during which time, some 10 000 km of river valley were inspected in a total area of 500 000 km^2. Profiles were made for 7 500 km of the valleys, and of the order of 200 potential dam sites were examined. The field work consisted of two main phases. The first was an aerial survey to describe the general character of the rivers, and to note possible hydropower sites. This was followed by the second phase, a helicopter surface examination of the previously selected rivers. The dam sites were appraised, and elevation data obtained for the plotting of profiles and the vertical control of photogrammetric mapping. Any sites previously mapped by other agencies were again studied by CANAMBRA. The geological survey consisted of a surface examination of the dam sites and surrounding region. Sources of construction materials were sought, and where applicable, the depth of material overlying the bedrock was estimated. Sites were then selected by the field engineer with the aim of making optimum use of natural fall in the rivers.

Results of the field work were given to the Design and Estimates Group for their preliminary assessment. Promising sites were mapped by the Photogrammetry Section, unless they had previously been mapped. If the sites were considered too costly, or too small, they were eliminated from the study.

The South Central Region survey of hydraulic resources covered an area of 500 000 km^2, in a period of less than two years, and had to employ approximate or "short-cut" survey methods. Very little information was available prior to the survey; there were almost no suitable maps or geological information(501), and hydrological data was scanty(502). Therefore, some of the information presented in the inventories could not be regarded as accurate and, while the resulting site data made it possible to compare the relative merits of the sites, to arrive at a good preliminary estimate of the potential of the basins and a rough magnitude of the cost of the power, more studies were necessary in order to establish the optimum development schemes of the rivers, and to make accurate power and cost estimates. The upper and lower limits for including projects in the inventory were US$ 500/kW, with a minimum capacity of 10 MW continuous. Under circumstances differing from those which existed at the time of the study, some sites which were rejected at that time may prove more viable in the future. Nevertheless, the inventories provided a good overall picture of the magnitude of the hydraulic potentials of the river basins studied, the scale of costs and a fair method for the comparison of sites(503,504).

A cost estimating procedure was established in keeping with the available data. Cost curves were prepared to provide total generating station costs, including power house structures, turbines, generators, auxiliary electrical equipment, miscellaneous mechanical equipment, and step-up transformers. The estimates included all capital costs involved such as land acquired, rights of way, relocation of highways and railroads, access, direct cost of structures and equipment, contingencies, overhead or indirect costs and interest on money borrowed. The costs included the high-voltage side of the principal step-up transformers.

Three types of project were considered; power and storage together, power only, and storage only. Where power was involved the projects were considered both as "first-added" and "with upstream regulation". For the power and storage projects the cost was divided into a "power component" and a "storage component". The specified index capacity (55% capacity factor) was always stated at a reservoir head corresponding to mid-volume of live storage, and the installation then rated at maximum reservoir level.

All the costs for the inventory estimates were in equivalent United States dollars. The cruzeiro portion was assumed to be 75% of the total cost, and was converted at the Purchasing Power Parity Rate (PPPR)* of US$1.00 = Cr$7.34 which is the rate used in the original conversion of cruzeiros to dollars in 1963. Conversions from cruzeiros to dollars, and vice versa, were made at the Purchasing Power Parity Rate of Exchange, based on US$ 1.00 = Cr$ 18.00 in 1937. The PPPR was constantly changing and, for many purposes, the

* For a realistic rate of exchange to convert cruzeiros to dollars and vice versa the Purchasing Power Parity Rate of exchange was used. This varies directly with Brazil's wholesale price index and inversely with that of the United States. 1937 was taken as the base year with an exchange rate of Cr$ 18 = US$ 1 (506).

inventory cost estimates had to be re-converted to dollar and cruzeiro portions, using the original 1937 PPPR, and then adjusted using the latest PPPR(505).

Direct costs for each project included civil works (dams and spillways), land costs, storage outlet works, unit prices (using charts of what was considered to be representative unit cost for Brazilian construction), and generating equipment. In addition, contingency allowances were applied, generally 20% for underground work, 15% for other civil work and 10% for equipment. No allowances were made for provision of navigation facilities or for future expansion of generating facilities. The indirect costs considered were the cost of the camp and construction plant, including operation and maintenance, estimated at 13.5% of the total direct cost (excluding land), owner's administration and engineering costs, which varied between 20% and 45% of the total direct cost, depending upon the size of the project, the contractors' fees and administration costs, interest during the construction, computed at an annual rate of 10% on half of the total of the direct plus indirect cost for two years on a small plant extension, to six years on a 4.0 GW project, and, lastly, relocation costs for highways and railroads(507). It should be noted that no allowances were made for the costs of resettlement of peoples displaced by reservoirs, or for environmental protection. The sole aim of the CANAMBRA studies was to identify hydraulic sites for power production alone.

Surveys - Feasibility studies

On completion of the inventory, those sites offering attractive prospects for inclusion in the development programme envisaged up to 1980, were studied in greater detail, in order to define more fully the engineering needs and to provide more reliable estimates of power capabilities and capital costs. These were called feasibility studies and comprised:

- site maps at scales of 1:2000 or 1:5000, with 2 m or 5 m contours,

- subsurface exploration by core borings, test pitting, auger boring and seismic profiles,

- investigation and testing of quantity and quality of local construction materials

- water surface profiles and soundings, and

- regulated flows, design floods and tailwater curves as derived from hydrological studies(508).

As in the case of the inventory studies, the primary consideration of a site was its economic viability. Estimates of capital costs included the direct and indirect costs together with contingencies and were based on the following assumptions:

- international competition for contracts,

- no imposition of import duties,

- inflation of the cruzeiro in accordance with Index Number 2 of the Conjuntura Econômica of the Fundação Getúlio Vargas,

- inflation of US dollars according to the indices of the US Bureau of Reclamation,

- interest rates during construction of 10% per annum, and

- cruzeiro to dollar conversions, and vice versa, in accordance with the Purchasing Power Parity Rate of Exchange(509).

According to the CANAMBRA definition, a feasibility study was:

> "A site study based on reliable topographic site maps, limited but reliable foundation and construction materials investigations and careful analysis of the best available hydrological data, for the purpose of establishing the technical feasibility of a project and of preparing reliable preliminary cost estimates. The feasibility study does not include determination of availability of a market and therefore does not confirm the economic feasibility of the project insofar as a market for the power is concerned, market studies being outside the scope of the study. The feasibility study ends at the low tension side of the step-up transformers"(510).

A feasibility study of this type was intended to confirm the preliminary estimate of the cost of power from a selected project, and was to provide a basis for any future investigations, design and financial planning. It was designed to give information on which to base certain simplified assumptions:

i. the cost of the firm power at a plant, capacity factor of 45-50%, at lowest drawdown, as a first stage of development,

ii. the cost of providing, in the initial layout, for future additional capacity which will allow a plant capacity factor of the order of 40% when the upstream stages on the river are fully developed, and

iii. the cost of additional capacity in order to provide a plant capacity factor of 40%, to be installed in the future.

The field investigations were to support the design and cost estimates for a selected scheme. They included:

- carriage of levels to the site,

- photogrammetric mapping using vertical aerial photographs, scale 1:10 000, for the compilation of maps, to a scale of 1:10 000, with a 10 m contour interval,

- ground surveys,

- river soundings and water surface profiles,

- installation and observation of water level gauges,

- core borings, auger borings and test pits,

- seismic refraction traverses,

- geological mapping,

- collection and testing of construction materials, and

- assessment of lands to be inundated.

The feasibility studies were limited in that they did not ensure the economic feasibility of a project. They did not consider the load to be served, the system load factor, the cost of transmission, the function of the project in an integrated system, and the comparative cost to the power produced by other hydroelectric, thermal or nuclear powered stations. However, should any of the projects be built, the feasibility study information will provide a sound basis for further detailed work. CANAMBRA expanded and extended the studies to include:

- foundation exploration and evaluation,

- location and testing of construction materials,

- river soundings,

- stage-discharge relation at tailrace,

- establishment of optimum head and tailwater levels with respect to existing or future projects in cascade,

- determination of the design flood,

- reappraisal of land values,

- installed capacity with respect to existing load and system conditions,

- model studies of spillways and other hydraulic components, and

- selection of civil structure types(511).

The cost items included in the feasibility study estimates were the capital costs involved including purchase of land, rights of way, road and rail relocations, access, direct cost of structures and equipment, contingencies, overheads and interest on money spent during the operation. The estimates covered the system from generation through to the low voltage side of the main step-up transformers. For each scheme, two cost estimates were prepared, and occasionally a third one, if time allowed.

The first estimate, considered to be the more representative, for each project feasibility study, was an estimate of the cost of providing the available power for run-of-river plants, at a capacity factor of 59%, at normal head. For plants with reservoir drawdown, a capacity factor of 65% was used at minimum head. Structural provision was made for extension of the installation at a lower capacity factor, normally below 50% in the first case, and below 59% in the other. The second estimate was the cost of providing the available power at the lower capacity factor, and the difference between this and the first estimate gave the incremental cost incurred in the installation of the additional generating capacity. The third estimate was for the cost of installation, at a later date, of the additional generation capacity which had been provided for in the first estimate.

The estimates consisted of two currency elements. All the services and equipment available in Brazil were costed in cruzeiros, whereas those which had to be obtained from overseas (assumed to be turbines, generators, electrical equipment accessories, part of the engineering cost and interest during construction) were estimated in US dollars. The latter generally amounted to 20% to 30% of the total project cost. The cost indices used for the feasibility study estimates were the same as for the inventory study estimates (see p. 192) but all the estimates were adjusted to June 1965 figures, in which US$1.00 = Cr$23.25.

The items included for the direct and indirect costs of the feasibility studies were the same as for the inventory studies, but for the plant and camp (construction and operation) the allowance made in the first estimate was 5.5% of the total direct cost for construction with 3.75% of the total direct cost for operation and maintenance. These allowances were then increased by 15% for reasons of contingency. For the second estimate the operation and maintenance charges were increased in proportion to the extension of the construction period. The owner's administration costs were allowed at

2.75% to 12% of the total direct cost, according to project size, and owner's engineering allowances were from 1.75% to 8% of the total direct cost. In addition, a contingency allowance of 15% was added.

The total interest during the construction and financing phase was paid at an annual rate of 10%. It was assumed that the interest would cease to be charged on units once they had been commissioned. As a result, calculation of interest would be on an increasing balance until the first unit was commissioned, and, thereafter, it would be calculated on a reducing balance.

Methodology adopted by the Brazilian Power Planning Sector.

Planning within the Brazilian electrical power industry is currently undertaken according to guidelines set out by the Diretoria de Planejamento e Engenharia of ELETROBRAS, in "Metodologia para o Planejamento de Expansão do Sistema Elétrica Brasileiro"(512). The objective of setting down these guidelines was to identify the development needs and the instruments and criteria for planning; to characterise the methodology for the planning of the expansion of the Brazilian electrical system; and, to identify the different stages in the planning process.

The aim of the Brazilian electrical power industry was set down as:

- to meet the electricity needs of the country, making the expansion of the power industry compatible with the market requirements, defined in terms of quantity and conditions of supply.

- to contribute to the development of Brazil by:

i. participating in rationalization of the energy industry,

ii. promoting, wherever beneficial, the substitution of non-renewable and/or imported sources by renewable and/or national energy sources,

iii. encouraging the more appropriate use of electrical energy,

iv. supporting the national equipment and service industries, and

v. participating in multiple development programmes of energy resources(513).

Expansion Problem

Most of the hydraulic potential in the regions close to the load centres has been exploited. For further expansion of the generating capacity of the Brazilian electrical power industry, it has become necessary to look to more distant hydraulic sources or alternative sources. The principal alternatives, as outlined by ELETROBRAS, are the exploitation of the basins of the rivers Uruguaî, Iguaçu, Paranaiba, Jequitinhonha and São Francisco; the use of the rivers in the Amazon basin, which will require transmission of large blocks of energy over long distances; the construction of very small stations close to the load centres; the reduction of costs by multiple river use; use of existing coal reserves in the South; and use of nuclear power or non-conventional energy sources.

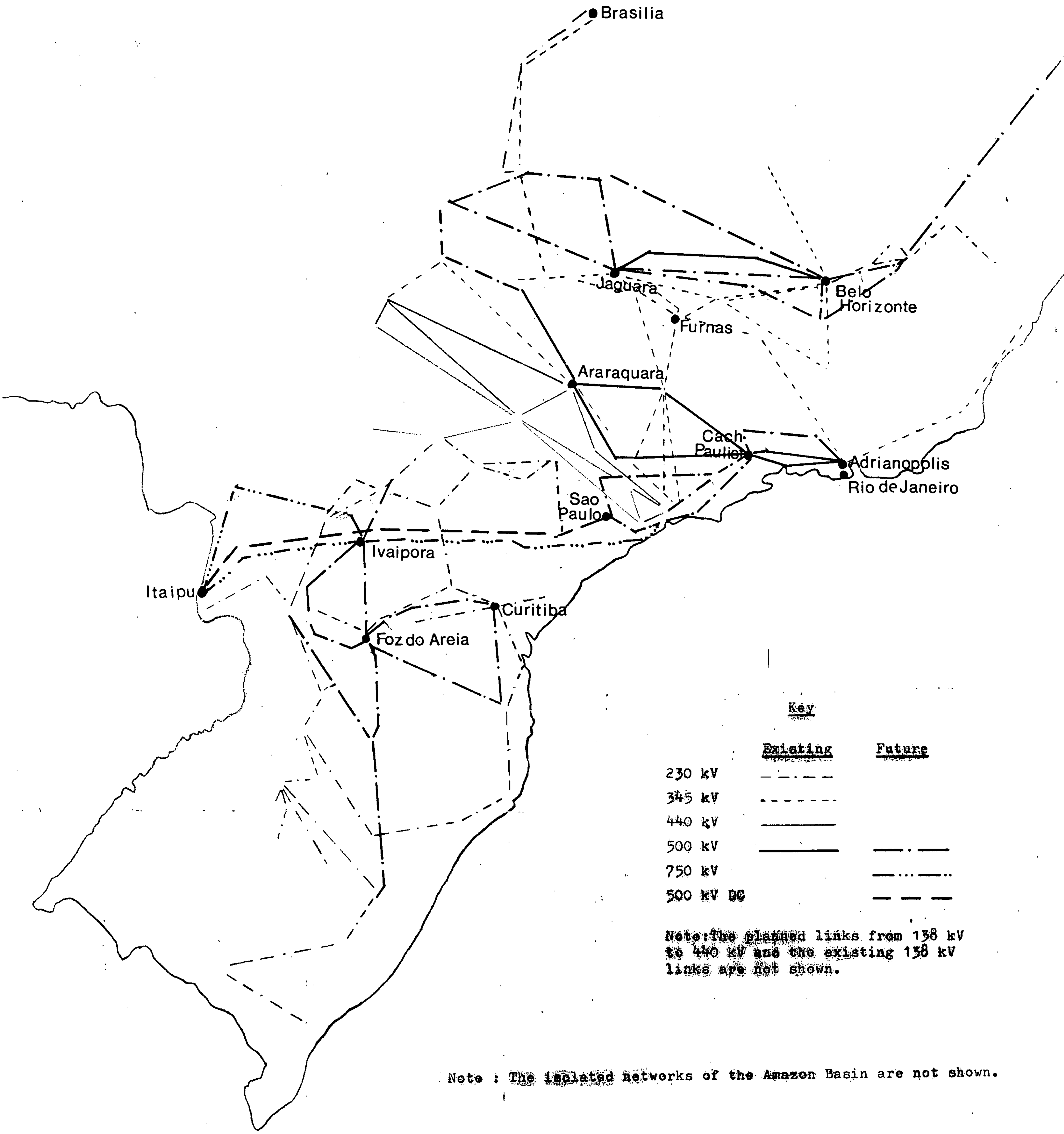
It is important to note that ELETROBRAS considered the perspectives for medium and long term planning to be distinct. In the medium term, the problem is centred on the choice between hydroelectric stations, situated in the river basins closest to the load centres, nuclear power stations and coal-fired stations, depending on availability of financial resources. In the longer term, however, the fundamental problem is one of the degree of technological development required, principally with respect to the transfer of energy from Amazonia and to the development of nuclear power.(Fig.5.1)

The Planning Process

Initially, planning within the Brazilian electrical power industry was guided by foreign consultants, e.g. CANAMBRA, but gradually, the principal concessionaires such as FURNAS (see p.154), formed planning teams which developed methodologies and criteria more appropriate to the Brazilian situation.

The principal determinant in the proposed expansion of an electrical power system is the evolution of the energy demand. This requires a forecast of the long term energy requirements, but given the high degree of uncertainty inherent in such long term studies, which are dependent upon the analysis of the change in the broad macroeconomic and demographic factors, the forecast can only supply the most probable value for each year. The planning process is a continuous one, each plan, as it is developed, taking into account the future evolution of the system. However, the decisions taken according to one plan put constraints upon the elaboration of the next. Decisions for large generating plant must be given a lead time of about eight years, therefore, it is necessary to analyse the requirements which will have to be met over a period of some fifteen

Figure 5.1 : Brazilian Electricity Transmission Network



Note : The isolated networks of the Amazon Basin are not shown.

Source : Departamento de Sistemas Eletricas, ELETROBRAS, 1978.

years in order to ensure that they are met on time.

For transmission lines, the time between planning and operation is shorter, about three years. This implies that a sufficiently detailed analysis of the transmission network could be done over a five year period. However, decisions over a period of twenty to thirty years, are necessary to identify the potentials of, and complete developments in, river basins distant from the load cetres, development of the technology for long distance transmission of large power blocks, and advancement of new generation technologies.

ELETROBRAS has recommended that the planning process consist of three principal stages, a long term analysis with a thirty year horizon, a medium term plan for the development of the first fifteen years and a five year plan covering the first five years. The long term plan would permit identification of the principal lines of development of the system and the fixing of the limits of the medium term expansion programme in terms of the generating capacity and the needs for development of technological and industrial processes.

The medium term plan is seen as establishing the expansion programme of the electrical power industry and combining the results of the long term analysis with the current conditions. In the short term plan, adjustment is made to the expansion programme of the generating capacity, and a detailed programme of expansion to the transmission system is presented.

Methodology and Planning Criteria

Long term planning

The initial analysis determines the composition of the generating capacity at the end of the thirty year horizon, in order to ascertain the optimal economic participation of the various generation sources in eg.2010 AD. The principal lines of necessary technological and industrial development are characterised, as a function of the minimum programmes of improvement of these sources, in order to establish the development of the system to 1995, 2000, 2005 and 2010 AD.(Plano 95 etc).

The principal determinant of the expansion in the electrical power system is the growth of demand, and it is necessary to forecast the requirements of the market for any future period. Given the long term uncertainties, the forecast can only give a probable value for each year. In Brazil, detailed forecasts have to be made at the regional level in view of the wide geographical dispersion of the load centres.

Long term forecasting of the Brazilian power market uses a single reference, based on the likely increase of the economy and population. The role of energy of hydraulic origin will continue to be the most important for studies made. The information available on hydraulic sources can be divided into three categories; inventoried, non-inventoried, and existing small stations which can be expanded. Using information from river basin assessment, all projects with an energy cost index, excluding transmission, of less than 80 mills/kWh (double the actual reference cost), are considered. For the non-inventoried river basins and small scale stations, preferably ones close to the load centres, in the absence of more precise information, the following classes of energy cost index have been defined :

i. up to 20 mills/kWh, the basin is considered for immediate development,

ii. 20-40 mills/kWh, considered for the future expansion programme, and

iii. 40-80 mills/kWh, considered as an energy resource.
(1979 figures)

The other sources of electrical power in Brazil are coal and nuclear fuel. For coal fired power stations, (recommended by ELETROBRAS to be considered throughout the periods of study), the locations for installation of stations have to be identified. The potential generating capacity of the coal reserves is then estimated, and the corresponding cost indices calculated. At the time of the report (1979), it was considered that nuclear energy would become the second major Brazilian energy source. The main information necessary for long term nuclear energy planning is a knowledge of the possible locations for installation of the nuclear power stations, their economic size, the estimate of potential of the Brazilian uranium reserves, and the energy cost index. Of fundamental importance to this analysis are the prospects for the use of new technologies, in particular fast-breeder and thorium reactors.

In a thirty year analysis it is necessary to consider the commercial development of new sources of energy for electricity. Not only must technological advances be made in electricity generation, but also in transmission, if the large energy potential of the Amazon basin is to be tapped. Possible transfer of large blocks of energy from the Amazon to the load centres in the South East has an important role to play in delineating the degree of competition between the various sources of energy. It is necessary, therefore, to estimate the unit investment costs for each possible transmission system.

The basic cost elements for the various energy sources vary widely, e.g. capital costs for hydroelectric power stations are much higher than for conventional thermal stations, but the operation costs are much lower. However, over a thirty year period, it is likely that the relationship between these various cost elements will change, with a consequent change in the economic viability of the different energy sources. It is necessary to allow for this within long term plans, and corrections must be made to the long term cost indices.

Medium term planning

The medium term analysis is used to establish the programme of works for the period 1980-1995, and to identify principal restrictions to its implementation, and wherever possible,the alternative solutions. This study requires a more detailed probable forecast of the peak energy requirements,throughout the period, by region, and by enterprise. Owing to possible variations in the behaviour of the market, and in order to permit an analysis of its effects on the programme of works, high and low forecasts for the regional and overall requirements have to be made until 1990.

The long term analysis indicates the general lines of development in the electrical system, and establishes the generation projects and principal transmission trunks to be considered in the medium term. The medium term plans are considered in greater detail to increase the degree of precision of the information on costs, physical characteristics and construction periods.

The operating costs of the system are strongly influenced by the consumption of fuel by the thermal power stations. Therefore, the costs of the fuel to be used, be it oil, coal or nuclear, must be estimated. The programme of works is then determined by the direct comparison of the alternatives.

Initially, a minimum cost scheme is devised, and, gradually, alterations are made in view of the long term planning directives. The estimate for each programme is made in three stages:

i. determination of the conditions required to meet the energy balance,

ii. detailed analysis of transmission, and

iii. economic and financial analysis.

As well as studying the market requirements and the work needed to satisfy them, ELETROBRAS recognises that all planning depends on the existing conditions at the time of execution of works, with respect to financing, relationships between companies, general lines of future operation of the system, and legislation on matters concerning the electrical power industry.

Short Term Planning

All the decisions or possible courses of action to be taken in the short term are derived from the long and medium term studies. These have to be made along lines which make it possible for hypotheses to be transformed into decisions. Although the locations of power stations and other data are well known in the initial years of the planning period, and the number of possible strategies are limited, it is only in the short term that it becomes possible to complete sufficiently precise and detailed studies for each hypothesis.

Plan of Action

This is the resultant programme derived from the long, medium and short term analyses. It consists of:

i. definition of the works which must begin in the period defined, e.g. 1979-80,

ii. definition of the projects which must be studied in detail at that time for execution in the medium and long term,

iii. outlining the alternative methods for choosing the various hypotheses for market forecasts and scheduling of works,

iv. definition of the programmes of technical-industrial expansion to be initiated in the defined period, e.g. 1979–80,

v. suggestions for finance of the execution of the short and medium term programmes of works,

vi. suggestion for legislative changes in the electrical power industry, and

vii. definition of studies necessary for the improvement of the long, medium and short term analyses(514).

Resources available, their effect on planning

The provision of electricity for consumption within Brazil has been affected as much by the availability of natural resources as by other determining factors of a political, economic and institutional nature(515). Assuming adequate financial resources, the decision making authorities have given preference to the different initiatives of the electrical power industry according to their origin (national or foreign, private or State, Federal or State). Other options have been between concentration or decentralisation of generation installations in local or regional systems. However, the market prospects, in terms of their size, geographic concentration, and dynamism remain the fundamental aspect of planning.

Conversion of suitable forms of energy into electricity has to guarantee continuous supply, with stable costs. The useful life of an installation will be largely determined by whether or not the choice of site has been economically sensible, especially as generation and transmission systems cannot easily be converted to uses other than those for which they were originally planned. As a result, a forecast of future operating conditions should not lessen the useful life initially forecast, as a result of economic and technological obsolescence. Preference should be given to renewable sources of energy in order to avoid situations such as arose during the world oil crisis in 1973, when the cost of fuel for the oil-fired power stations rose drastically.

For forcasting purposes, the useful life of an electrical power industry installation is normally taken as 20 to 50 years, and it is necessary, therefore, to have a compatible time scale when planning such installations, coupled with good knowledge of the primary sources of energy available, and their compatibility in economic terms. In Brazil, such knowledge is often limited. In the case of hydraulic resources, the available hydrological records for the North

East, South East and Southern Regions generally cover about 40 years, but in the Northern Region they cover considerably less and are often non-existent. Despite ELETROBRAS's complacency over the 40 year records, the hydrological data networks in most areas are far from comprehensive,although a great expansion did occur in the 1960s(516). However, ELETROBRAS uses the hydrological series available, in a general way, in order to estimate the available hydraulic potential, in addition to the hydrological characteristics upon which the design of the principal dam structures, such as spillways and escape channels, depend. In practice these estimates are based as much upon simulated situations, corresponding to those recorded, as upon situations which are statistically inferred from the recorded series.

A major difficulty is to ensure the uniformity of the criteria for project estimation, and the compatibility of precision of the basic data. Such data must cover natural flows, conditions of supply and cost of primary materials, equipment delivery times, technological specifications, direct and indirect construction costs, cost of the land to be inundated behind the dam, and facilities for access to the construction site. Standard criteria were established in 1963(517), in the same year as the initiation of surveys in the South East Region under the supervision of the Comitê de Estudos Energéticos, which had been created for this purpose by the Ministério das Minas e Energia, along with representatives of other Ministeries.

In Brazil, the vast hydroelectric potential is the most important aspect of any planning for the expansion of the electricity supply industry. Through predominance and convenience, hydroelectricity is well established as the primary source of electrical power. However, the many hydroelectric power stations are complemented by the various alternative forms of thermal generation. Any planning of generation systems must take into account not only the characteristics of the different generating units, but also the characteristics of the associated transmission systems. Long distance high voltage power transmission is now a feature of the Brazilian electricity supply.

Of the alternative sources of electrical energy available, steam coal from Rio Grande do Sul is important because of its relatively low cost and the abundance of reserves. However, in the state of Santa Catarina the coal is preferred for use in the steel and carbon industries. In Brazil, coal tends to be used by the electrical power industry for the purpose of "thermal complementation", in which, beyond a minimum consumption,its use varies as a function of the hydrological season.

The planning of the expansion of coal-fired power stations has to consider, simultaneously, the requirements of the electricity supply industry, and those of the coal sector in order to maintain an economic rhythm of use, as well as those of the steel industry which has to rely on a national coal supply for part of its requirements. The prospecting for coal is the concern of CPRM, together with some companies and state organs concerned with mineral research. Coal resource exploitation comes under the jurisdiction of the Conselho Nacional de Petrõleo (CNP) and the Sindicato Nacional da Indũstria de Extração do Carvão (SNIEC), which includes representatives of the private mining companies(518). However, except in the southern regions of Brazil, the quality and quantity of coal for use in power stations is so low that its use is not considered, in the overall energy planning perspective, in the same way as hydraulic and nuclear resources.

Economic References Used for Planning

In June 1979, DEME produced the details of the economic parameters to be adopted by the Brazilian electrical power industry, particularly for the Plano 95, in order to guarantee the compatibility of the different regional plans being produced. For economic planning purposes the currencies used are the cruzeiro or the dollar, using the 30 June 1979 exchange rate of Cr$25.60 = US$1.00.

In summary, the parameters outlined by DEME are:

i. notes upon the Brazilian energy policy, based upon official documents and government studies,

ii. the historical evolution and perspectives of the macro-economic totals, such as the GNP for Brazil, by region and by section of the population,

iii. the population increase; both urban and rural, including the growth of number of dwellings,

iv. the probable growth of the electrical energy market; this is outlined by class of consumer and by concessionaires; also included are the high market projections, as a function of an accelerated development of the economy and, alternatively, the substitution of petroleum derivatives by electricity,

v. the rate of social exchange, in terms of purchasing power parity, observing the real cost of obtaining foreign exchange credits for Brazil,

vi. the discount rate, in terms of the marginal efficiency of capital in the economy, keeping in sight the investment alternatives,

vii. the availability of petroleum, and forecasts of future costs, and their response to national and international events,

viii. the availability of uranium, and future costs for electricity generation, with respect to the tendencies of the costs of the mineral and fuel cycle to rise, and

ix. the availability of steam coal, and forecasts of future costs with respect to all its uses within the Brazilian economy(519).

Many of the economic indicators used are calculated by DEME itself, and they differ from the projections published by the Fundação Getulio Vargas. Nevertheless, the Brazilian electrical power industry bases its estimates upon the DEME figures(520).

Market Projections

Three market projections are used by the Brazilian electrical power industry. These are the Mercado Provável (Probable Market), the Mercado de Programação (Programmed Market), and the Mercado Alto (High Market). The forecasts for the future electricity markets are based on premises which have to be compatible with governmental goals and policies for overall, and sectoral, economic expansion. The premises adopted for the quantification of the Mercado Provável lead to average consumption levels, where the probability of these levels being exceeded is of the order of 50%. However, if expansion of the electrical system is only programmed to satisfy the Mercado Provável, the risk of deficit to the system is also about 50%.

In practice, an estimated security margin is adopted, and the final value used to programme the expansion of the demand is the Mercado de Programação, which is the sum of the Mercado Provável and the security margin. The upper limit of the Mercado de Programmação has been defined to correspond to the Mercado Alto, which would be reached in the event an accelerated expansion in the Brazilian economy, or from an extended substitution of petroleum derivatives by electricity.

As the mobilization of the resources necessary for large scale petroleum substitution would have a negative effect upon the Brazilian economy, the hypothesis of high economic expansion occurring simultaneously with effective substitution is not considered. Therefore, the probability of the Mercado Alto being exceeded is considered to be very small. The Mercado de Programmação estimates, therefore, lie between those of the Mercado Provável and the Mercado Alto.

Social Exchange Rate

For planning purposes it is necessary to be able to convert, to national currency, those costs defined in foreign currency, and vice versa. In any analysis of technico-economic alternatives comparisons of international prices are absolutely necessary.

The alternative projects selected usually involve foreign currency exchange of some sort (capital loans, equipment purchase).

In order to assess its effect upon the national economy independently, of the fluctuations in the official exchange rate, a "social exchange rate" is used. The social exchange rate used in Brazil has been calculated according to two different theoretical bases, which both yielded similar values. The first is based upon the purchasing power parity (as used by CANAMBRA, see p.193) where the relative variation of the exchange rate between two currencies is said to be proportional to their purchasing powers in the respective countries. The other theory directly considered the balance of payments through the traditional model of partial equilibrium of the foreign exchange market.

Discount rate

Whichever concept is adopted for determination of this rate: the Keynesian argument derived from the theory of investment, and founded upon the concept of the marginal efficiency of the capital being equal to the rate of interest in a capital market in equilibrium; or the concept that this rate derives the social value of investment, involving considerations with respect to the redistribution of the income in favour of future generations; the concept of the discount rate is clearly different from that of the rate of interest.

The discount rate adopted by DEME comprises, in essence, an element of the economic policy which directs the planning towards more capital intensive alternatives which have lower operating costs when the discount rates are low, and vice versa. Higher discount rates can lead to immediate policies which more strongly emphasise costs and benefits nearer in time, while lower values, according to DEME, no longer tend to reflect the scarcity of resources in the economy. For the calculation of the marginal capital efficiency, the following parameters were considered: gross fixed capital formation, depreciation, liquid fixed capital, land values, nationally funded capital and return on capital. In the historical period considered, the discount rate was calculated using the concept that the marginal efficiency of the capital was 6.3% per year. Examination of the real value of the minimum market interest rates would lead to values of the same order of magnitude.

Due to the lack of capital resources for public investments and, as a result of the structural changes occurring within the country's economy, which required the rapid expansion of the investments to higher levels than those at the start of the 1970s, the rate used, of 7% per year, was slightly higher(521).

In addition to the economic references published by DEME, ELETROBRAS also publishes the "Orcamento Plurianual do Setor de Energia Elẽtrica" (Multiannual Budget) This summarises the information needed to estimate the the resources available for investment in the electrical energy programmes, which are forecast for a five year period and updated annually. This economic and financial planning instrument aids the standardization of the reference data for the entire electrical power industry and, in particular, creates a standard data base, thus leading to a more refined system for selection of projects(522).

It should be reiterated, that, until the Brazilian electric power industry became integrated, such reference data did not exist, but they are now facilitating the more complete integration of the industry.

Criteria of Supply

In Brazil, the level of electricity supply available in any period is not constant. It depends on the randomness of the natural flows of the rivers supplying the hydroelectric power stations, and the occasional non-availability of conventional thermal and nuclear power stations. In formulating an expansion programme, it is necessary to compromise between the risk of not meeting requirements and the limits of the resources available. Due to the complex interrelationship of the electrical power industry with the rest of the Brazilian economy, it is impossible to know, a priori, the level at which this compromise must be made.

Traditionally, planning of system expansion has focussed on meeting a pre-fixed criterion of supply. The Brazilian generating system is predominantly hydroelectric, and all emphasis has been given to the seasonal availability of water. The Brazilian criterion used for hydroelectric power planning is, " . . . the system must be capable of meeting the market requirements, for any hypothesis based upon the repetitions of the historic hydrological series recorded"(523). To date, thermal stations have been considered in a simplified form, with average factors of availability, but the analysis used is now being refined. This is to take into account thermo-nuclear stations, which have been found to have high breakdown rates and long periods of non-availability.

The comparison between the availability of energy and the peak demand on the system, according to the market demands for each period within the horizon of study, is usually called the "balanço energético"(energy balance). This indicates the availability of energy and peak power for each possible configuration of the system taken separately. Such an analysis can be made using relatively simple mathematical relationships, or by using a computational process which simulates the behaviour of the energy configuration for each hydrologic sequence which has been recorded or postulated.

For an hydraulic energy system, the firm energy of a particular configuration is defined as the greatest load possible which can be supplied, without interruption, in the case of a repetition of the worst recorded hydrological sequence. The critical period is defined as the time interval between the instant when the reservoirs are completely full, and the instant when they reach their minimum level, without a total intermediary refill. The guaranteed peak power capacity is the total which the system is capable of generating, and the minimum value of the total available capacity of the system corresponds to the availability in the last month of the critical period, when all the reservoirs are empty. In a more precise study, a "balanço dinâmico" (dynamic balance) is prepared, in which the energy balance at any instanted is computed directly by means of computer simulation models.

The adopted supply criteria show a number of limitations. Deficits will occur in a situation of worse critical hydrological conditions than previously recorded. But, the probability of the repetition of the worst hydrological period is so small that, if this criterion were adopted for planning, it would result in excessive investment in the electric power industry. As a result ELETROBRAS has developed a planning methodology based on the case of probabilistic criteria as a substitute for the actual criteria previously used. Studies for the reformulation of the present criteria are in progress, but are being set back by the increased computational effort required for analyses of this type.

The Generation Models

In the first stage of establishing the model, the sequence of entry into operation of the hydroelectric power stations is determined so as to guarantee the desired level of supply. The size of the power stations, and the time taken for the market to absorb their outputs totally, is not considered at this stage. They are regarded as being small relative to the total capacity of the system. The optimum level for the output of the thermal power stations is fixed by empirical criteria.

Two simulation models are used for this phase:

i. The Modelo de Ordenação de Usinas Hidro e Termoelētricas, determines the sequence for stations to be constructed. This model orders the power stations considered in the expansion alternatives, using cost/benefit indices with respect to the energy configuration existing at the time of proposed entry of the power station into the system.

ii. The Modelo de Avaliação de Sistemas Hidrotērmicas (MASH), determines a simplified energy balance, which allows an initial adjustment of the dates of entry into operation of the planned stations. It adjusts, with time, the construction sequence for given stations, in order to meet the demand forecast for energy and peak power. Using approximate relationships this model automatically calculates the energy availability and peak power demand. Its flexibility allows a large number of alternative initial operation schedules to be estimated, in energy terms.

In the second stage, each alternative is simulated using models in which, for a particular energy balance, the market requirements will be matched to the availability of energy and peak power in the system. The principal models used are:

i. The Modelo de Simulação a Sistema Equivalente (MSSE), based on the representation of the total hydraulic system by a single equivalent station. It is used to determine the firm energy.

ii. The Modelo de Simulação a Subsistemas Equivalentes (MSSSE), is an extension of MSSE in that it various equivalent interconnected systems and permits dynamic simulations.

iii. The Modelo de Simulação a Usinas Individualizadas (MSUI) considers the operation of the system through a detailed representation of the generating system.

iv. The Modelo Linear de Intercâmbio entre Subsistemas (MISS) is a development of MSUI able to incorporate the restrictions of energy flow between regions.

There are also seven auxiliary models for the calculation of the reliability of the system, the determination of the policy for thermal station operation, and control curves for reservoirs levels.

Two models are used in the financial stage of planning:

i. The Modelo Econômico de Cálculo de Alternativa (MECA) determines the annual disbursements for the updated expansion programme, in addition to the average costs for energy and peak power, and

ii. The Modelo de Análise Financeira (MAFI) analyses the development of the financial situation of the energy sector for a predetermined expansion programme, and determines the average tariff.

The methodology used is continually revised, and this has led to the need for the development of analytical processes for long term energy strategies(524,525).

Despite the use of these computerised planning models for the best use of resources it must not be forgotten that the objective of ELETROBRAS and the Brazilian electrical power industry is to meet all the electrical needs of the country. One of its duties is to ensure compatibility between the expansion of the electrical sector and consumer demand and, at the same time, to direct this expansion in a manner which will contribute to the country's overall economic development. In practice the responsibilities of ELETROBRAS include:

i. participation in the rationalization of the power sector,

ii. promotion of the advantageous substitution of non-renewable and/or international energy resources by renewable and/or national ones,

iii. encouragement of the more appropriate and economic use of electricity,

iv. support of national industry for equipment and services, and

v. support of programmes for the multiple use of water.

This last duty is often in conflict with what, hitherto, has been been observed in practice. To date, most hydraulic developments in Brazil have been for power, and other uses have developed only latterly. In the case of the rio Paraība, which flows through a highly populated and industrial area, it has become necessary, in recent years to co-ordinate the multiple use of its water(526). More generally in the South East, rivers have been used for drinking and industrial water supplies and effluent disposal.

Most of the operational models, as used in Brazil, are for analysing the use of water resources for power, despite the fact that the thermal power stations may offer considerable flexibility to the choice of operation policy. Except in the Amazon region, where they are used to supply isolated systems, thermal stations have up to now been seen as providing a power supplement to the hydraulic system in dry periods and times of major electricity demand. Their participation is relatively small, accounting for some 19% of the actual system output, but they are responsible for a major part of the operational cost of generation(527). This represents a relatively high cost for ensuring reliability of supply.

CHAPTER 6

Hydroelectric Power Development in the Amazon Basin

"The largest of the remaining natural areas left on this planet to succumb to man's insatiable hunger for power and domination, or to civilization's alleged material needs, is the vast Amazon region with its great yet extremely fragile equatorial rain forest ecosystem..."(528).

Ever since its discovery, the Amazon region, or Amazonia, has caught the imagination of man. The area of Amazonia Legal* is 5 057 490 km^2, 59% of the area of Brazil. The river Amazon, from which the region takes its name, rises as a stream at an altitude of over 5 000 m in the Peruvian Andes, only 192 km east of the Pacific Ocean. Its exact length is disputed, but it is about the same length as the River Nile (6 500 km), which makes them the two longest rivers in the world. Its total watershed area is 7×10^6 km^2, of which 4.7×10^2 km^2 are in Brazil. It has over 1 100 tributaries, 17 of which are greater than 1 600 km long. The region contains parts of six Brazilian states, and three territories. The estimated population in 1970 was 7.5×10^6, which gives an average population density of 1.5 km^{-2}. The two major cities in the region are Belém, at the mouth of the river, and the free port of Manaus, sited just upstream of the confluence of the rio Negro and the rio Solimões. It is at this point that the river takes the name Amazon.

The mouth of the river is 320 km wide, and even 1 600 km upstream it attains a width of 11 km in places. It is navigable by ocean going liners to Manaus, 3 680 km upstream of the mouth; and,

* Amazonia Legal includes the states of Amazonas, Acre, Para and Mato Grosso, the northern half of Goias and the territories of Rondonia, Roraima and Amapa.

including the tributaries, the length of navigable waterways in the Amazon Basin is greater than 80 000 km. From the base of the Andes, most of the river flows through land which is almost flat, the overall gradient is 2 $cmkm^{-1}$, and, if considered from the base of the Andes, this falls to 0.4 cm km^{-1} (529).

The Amazon river is thought to have been first discovered by the Europeans at the end of the fifteenth century, and was first navigated, accidentally, in 1542. The indigenous inhabitants are the Amerindians, encompassing 100+ tribal groups, and 10+ different language types(530). From 1570, small settlements and Jesuit missions were established along the Amazon. The small agricultural clearings they made were worked by "tamed" or enslaved Amerindians, however, many of the Indians died as a result of maltreatment, or exposure to European diseases; others chose to retreat further into the forest. The first ascent of the river was made from Belêm, in 1685, by the Jesuit priest, Samuel Fritz. He mapped the region carefully and, until recently, his work had been the basis of all maps of the area. As the region is so large, study of it has tended to concentrate in a few small areas of specific interest or accessibility.

The first scientific exploration of the Amazon began in 1736, with the measurement of the arc of meridian for the French Academy of Sciences, by Charles Marie de la Condamine. Two Brazilian naturalists, Lacerda de Almeida and Rodrigues Ferreira, visited Amazonia between 1781 and 1792, and their accounts whetted international scientific curiosity. At the beginning of the nineteenth century, the Bavarian biologists, K.F.P.von Martius and J.B.von Spix, made extensive studies, and published the monumental flora "Flora Brasiliensis"(531). Such studies encouraged other naturalists, including Henry Walter Bates, who studied the entomology(532), and Robert Spruce, who studied the botany(533). The visits to Amazonia by Alfred Russell Wallace stimulated him into formulating the theory of evolution by natural selection, which he and Charles Darwin published in 1858(534).

It was not until the advent of steamships, and the resulting ease of communications, that Amazonia began to undergo integration with the rest of Brazil. Late in the nineteenth century, Amazonia rose to worldwide importance as a result of the commercialization of rubber. The rubber tree is native to Amazonia, and had originally been tapped by the Amerindians for its latex. With the development of the vulcanization process, which improved the properties of the rubber, the rubber boom began. There was no planting of additional trees, increased production depended on increased exploitation of the natural forest by the introduction of more labourers. Brazilians seeking work flocked to the region, many from the drought ridden, poverty stricken North East. This was the first time, but was not the last that the North Easterners have turned to Amazonia for refuge (see p.231). The rubber boom lasted from the 1870s until to the outbreak of World War I, but the successful introduction of rubber seeds in the Orient, and the subsequent establishment of plantations there signalled the end of the Amazonian rubber trade.

Amazonia fell into a decline for half a century until the construction of the Belém-Brasīlia Highway, in the 1950s. Up to that time, access to the region was restricted almost entirely to that by boat, and when, in 1942, the country's coastal merchant marine services were paralysed because of World War II, the region was cut off from the rest of Brazil for two years.

The first serious steps to develop modern Amazonia were taken, in 1953, with the creation of the Superitendencia para a Valorização Econômica da Amazonia (SPVEA, Superintendency for the Economic Evaluation of Amazonia), by President Getulio Vargas. Finance for this organisation came from 3% of the total tax revenues of Brazil used to fund its operation. However, the new organization ran into difficulties, the finances never materialised, and its first five year plan did not receive the approval of the Congresso Nacional. The SPVEA never established authority over the states and municipalities in the region, and its only achievement was the commencement of the construction of the Belém-Brasília Highway.

When Castello Branco became President, in 1964, he brought with him several years of Amazonian experience, and when, he was informed that SPVEA would have to be completely overhauled, if it were to prove effective in the development of the region, he replaced it, in 1966, by the Superitendencia de Desenvolvimento da Amazonia (SUDAM, Superintendency for the Development of the Amazon). SUDAM was to be the main arbiter over the placing of all the new Federal funds for the region. The existing government rubber bank, the Banco de Credito da Amazonia, was simultaneously transformed into SUDAM's financial agent, and renamed the Banco da Amazonia S.A. (BASA). Generous fiscal incentives were introduced in order to encourage Brazilian investment in the region, e.g. under law no.5174, registered companies could enjoy a 50% reduction in tax liabilities if the money saved as a result was invested in approved SUDAM projects in agriculture, cattle breeding or basic industrial development.

The Superitendencia da Zona Franca de Manaus (SUFRAMA, Superintendency for the Duty-Free Port of Manaus), was created at the same time as SUDAM, and legislation allowed goods to be imported into Manaus from anywhere in the world, without the payment of import duty. Between 1967 and 1970, the importation of goods through the zone doubled. The new free trade zone of Manaus was intended to persuade international firms to establish small factories there(535).

Principles for agrarian policy for Amazonia were first laid down, in 1970, in the Programa de Integração Nacional (PIN, Programme of National Integration). At the same time, the Instituto Nacional de Colonização e Reforma Agraria (INCRA, National Institute for Colonization and Land Reform) was created. INCRA decreed, in 1971, that the lands lying along a 100 km belt on each side of the roads in Amazonia were indispensible for national development, and it drew up plans for their colonization. The whole scheme was an unmitigated failure(536).

The construction of roads in the region has, probably, had the greatest impact. Not only have they opened up much previously inaccessible land, but also done immeasurable environmental damage(537). Essentially, any development programme in the region is hampered, not only by the general inaccessibility, but by land speculation by wealthy land owners, poor legislation over land titles, infertile soils and corruption. Those who come to the region poor, stay poor; those who come rich, get richer; those who were already there get driven off the land. As a result of such presence the environment of the region is suffering major and irreversible damage.

The Amerindians

Possibly the most emotive subject, when discussing Amazonia, is that of the indigenous peoples, the Amerindians. There is no accurate estimate of their numbers, figures range from 50 000 (538) to 180 000 (539). However, there is little doubt that, in common with other aboriginal groups, their numbers have been drastically reduced. Before the European invasion of the 1500s, it is thought that there were over a million people living in the Amazon area. This was estimated to have dropped to half-a-million by 1940 and to 100 000 by 1957 - all as a result of persecution and European diseases such as measles and the common cold (540). It is now reported that the Amerindian population is on the increase, possibly due to improved medical care and facilities, or possibly due to the desire to prove that Federal Government measures for protection of the Amerindians are working.

All activities with respect to the Amerindians have been fraught by lack of financial support and corruption. The government agency for administration of Indian policy is the Fundação Nacional do Indio (FUNAI), and any beneficial effects which it may have had, have been due to the dedication of its staff, rather than to support by the government. The Brazilian constitution provides that land inhabited by the indigenous Amerindians is to remain perpetually in their possession, but there are several specific cases when authorization by the President of the Republic for relocation of Indian communities can be made :

- to end fighting between tribal groups,

- to combat serious epidemics threatening the survival of a native community,

- to maintain national security,

- to undertake public works of interest to national development,

- to repress widespread disorder, and

- to work valuable subsoil deposits of outstanding interest for national security and development.

Legislation provided for Indian lands to be identified and demarcated by 31st December 1978, but due to budgetary and manpower constraints, coupled with the difficulty of locating uncontacted communities (without disrupting them) and identifying their area of habitation this has not been done(541). (See Fig 6.1)

At present there are four government parks for the Indians, the Araguaia, Xingu, Aripuana, and Tumacumaque, covering 3.7×10^6 ha and a further two are proposed. In addition, there are seventeen reservations scattered through Amazonia, and another seven are proposed (542). However, the clauses in the legislation allowing for relocation of the Indians makes their situation far from secure.

One of the principal threats to the existence of the Amerindians has been the Brazilian Government's efforts to open up Amazonia by means of highways. Not only do the highways cut through many of their reserves, bisecting traditional hunting grounds, but the dangers of contact and conflict with the construction teams are great. On construction of the Northern Perimetal Highway, diseases carried by the highway workers resulted in the decimation of Yanomamo

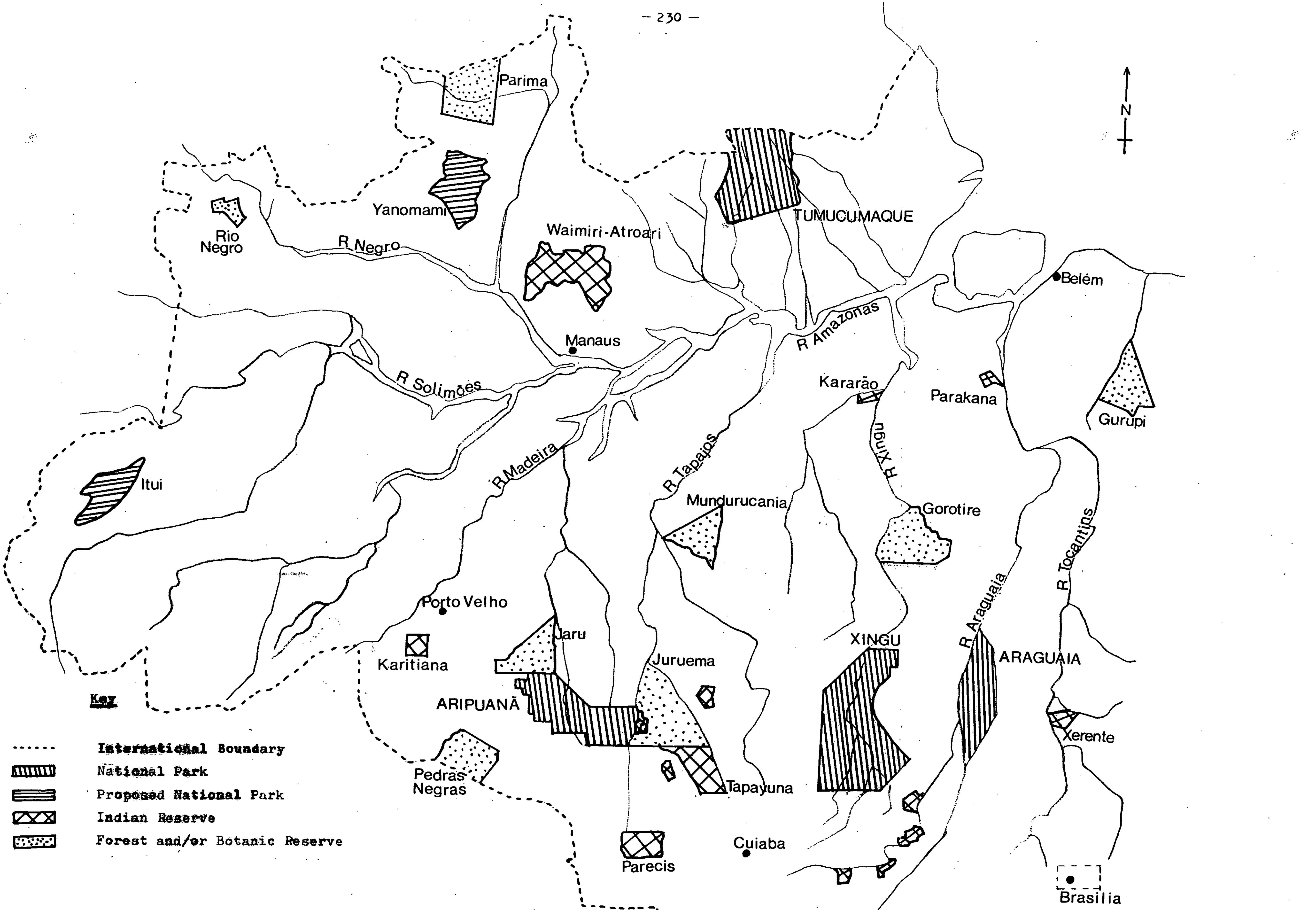


Figure 6.1 : Map of the Amazon Basin - showing existing and proposed Amerindian parks and reserves

Source : E. Brooks et al. "Tribes of the Amazon Basin in Brazil 1972" 1973, p.17.

villages, and the Indians were subsequently witnessed in a state of misery, sickness and shock(543).

The highway development programme began in the 1970s as a result of an impromptu promise made by President Medici, in 1970, when he was on a visit to the North East, at that time in the grip of one of its worst ever droughts. Without thought or understanding, he promised to open up the untold riches of Amazonia to poverty stricken North Easterners. Each family was to receive 100 ha of land, and it was proposed to build new, low-cost housing along the highways(544). The intention was to settle half-a-million peasants along the Transamazonica Highway by 1980. By mid-1978, only 8 000 families had been settled. However, this was of no consolation to the Amerindians.

Although many Brazilians claim to feel a great sympathy for the Amerindians, the settlers do not. It is a fight for survival on all sides. Many take the nineteenth century North America prairie view: "the only good Indian is a dead Indian", and it has been reported that, in many instances, FUNAI has all but given up protecting them(545). Land tenure in the Amazon is complex and, usually corrupt. Many of the small scale settlers have no title to the land they occupy, others have acquired title in good faith, only to find the land occupied by Indians, with the resulting conflict between two poor and under-privileged groups.

FUNAI teams have accompanied construction crews during the building of the Transamazonica and other highways, in order to attempt to locate Indian communities, in advance of construction, and to resettle them on equivalent land in a peaceful way(546). This has, in fact, resulted in armed hostility from the Indians in some cases. Although the official line is "contact but no conflict", violence does occur, and at least one survey party has been killed by Indians(547).

In spite of the Indians non-damaging relationship with the complex eco-system of the forest and their extensive knowledge of how to survive successfully within it, without damaging the valuable biological treasures it contains, the Indians are frequently being relocated from their traditional hunting grounds. Although the Amazon is covered by tropical rain forests, it is known that many tropical organisms are confined to particular narrow areas. The Amazon could be described as consisting of thousands of micro-regions, each ecologically distinct in terms of flora, fauna and soils. An Amerindian tribe understands its traditional haunts intimately, thus relocating it in a different region with a different biota, a different climate and different diseases is often disastrous(548). The depths to which some tribes have sunk is well described in the report of an expedition which visited the tribes of the Amazon basin in 1972 (549). Such ecolgical factors may be as detrimental to the Indians as is their conflict for land with the small scale settlers(550), although possibly there is a greater threat from the large scale colonizers. The problem of the Amerindians and their integration into modern society is a difficult one, and admirably expressed by one of the correspondents of the Financial Times, Hugh O'Shaughnessy,

> "The indigenous peoples have a knowledge of and relationship with nature from which we ourselves in modern Western societies could learn. Their disappearance would be OUR loss. At the same time I am also opposed to those who might be called extreme conservationists, anxious to

maintain such tribal peoples in their pristine state like so many flies in amber. I feel it is unrealistic and indeed unfair to the people concerned to attempt to do this. For good or ill they and we live on the same planet where communications and contact among peoples are constantly increasing. And while they should be protected against any frontal assault on their civilization they ought also to be given the opportunity to benefit from the positive aspects of Latin American civilization - be these in the realms of medicine, agriculture or other fields"(551).

Environmental Issues

The Amazon region contains the largest standing primaeval tropical rain forest, and the most diverse biological stock in the world. With the exception of untapped Amerindian knowledge, very little is known or understood about the complex ecosystem, and basic research is only now being pursued, principally by the Institute Nacional de Pesquisas da Amazonia (INPA, National Institute for Amazon Research).

There are many myths which have been perpetuated about the Amazon region; popularly, it has been regarded as a reserve of untold wealth, waiting to be tapped. In fact, most of its soils are of extremely low fertility and degrade rapidly once vegetation cover is removed. Although small clearings made by indigenous peoples will regenerate over the years, large, severely disturbed areas of rain forest do not have the capacity to regenerate(552). Not only does the forest not regenerate, but the land can normally only sustain crops for two or three years before being totally exhausted of plant nutrients.

Another popular myth is that the Amazon tropical rain forest is the world's lung. It has been suggested that the forest is a major source of the world's supply of oxygen and that destruction will lead to a depletion of oxygen in the atmosphere. In fact, in the stable ecosystem, as exists at present, the oxygen produced by photosynthesis during the day is reabsorbed by respiration at night(553). However, it still makes news headlines(554,555). Possibly, the greatest danger lies in the build up of carbon dioxide in the upper layers of the world's atmosphere due to clearance of large tracts of the forest by burning, and more importantly, by the burning of fossil fuels. At present the photosynthetic process absorbs much of this industrially produced carbon dioxide, but if the atmospheric levels of this gas continue to rise there is the possibility of an enhanced "greenhouse effect" with a consequent warming of the earth(556). However, it is also thought likely that two thirds of the carbon dioxide released from fossil fuels dissolves in the oceans(557).

Certainly the local climate could be affected by the replacement of the forest. Research in INPA has shown that about half of the rainfall in the Amazon basin is from water vapour released into the air as a result of transpiration. Replace the forest by grassland and there would be a drying trend in the climate, leading to desertification as has happened in north eastern Pará(558).

INPA is the principal research organ studying the Amazon region. It has divisions for botany, agronomy, medical sciences, ecology, fish and fisheries, chemistry and technology. There are 705 personnel employed by INPA, 157 are researchers, 285 research assistants and 263 administrative personnel. The area they study is 5×10^6 km^2(559). This represents a very small number of workers involved in trying to discover the secrets of a tropical rain forest which is being destroyed at a rate of 2×10^6 ha per year. The forest complexity is indicated by the enormous variety of flora and fauna, many species of which remain unknown to science, and it is an enormous pool of genetic material of great potential value.

Entrepreneurship

The most publicised form of entrepreneurship in Amazonia is the felling of trees for lumber, and in the popular press there are many "scare" stories(560). Foreign timber companies are apparently eager to exploit the wealth of the Amazon, and this is seen by the Brasilian Government as a way of helping reduce its foreign debt(561), and the Government has allowed the systematic plundering of the region for the last 10 years.

A blue print for the preservation of Amazonia was prepared in 1979. The intention was to place a new forest policy before the Congresso Nacional, in March 1980, based on ecological protection and development of economic potentialities. How much this will save the forest is debatable. Included in the blueprint were market studies of the internal and external use of wood resources, and studies of the economic viability of the use of the wood existing in the areas where deforestation will be necessary for public projects(562).

There is concern, within Brazil and abroad, over how much of the forest cover is being destroyed. The Brazilian space research agency, the Instituto de Pesquisas Espaciais (INPE) in co-operation with the United States National Aeronautics and Space Administration (NASA) is collecting data on the changes of the area of forest cover using the Landsat satellite. It would appear that in the area where forest cutting has, to date, been concentrated, in fact, only 7.5% has been cleared, and although existing legislation permits no more than 50% of any property to be deforested, in reality, often much less than this is cleared(563).

In addition to clearing for the use of the timber, large tracts of the forest are cleared for cattle ranching. Many of the livestock projects which have hit the headlines are, in fact, in the savannah of the States of Mato Grosso and Goiás. But for entrepreneurs with capital, large incentives have lured them and their enterprises into Amazonia. Incentives have included payment for land clearance, tax concessions, and easy credit facilities. Despite the fact that the land, once cleared, is unable to support agriculture for more than three years, the large land owners have usually made a handsome profit(564).

The one project which must be singled out is that of the American Daniel Ludwig. He is reported to have invested about US\$ 1×10^9 in the Jari project, which covers nearly 1.6×10^6 ha on the rio Jari in the state of Amapá, about 400 km northwest of Belém. His original intention was to clear the whole area and set up an enormous tree and rice farm. The project was started in 1967 and two species of fast growing tree were planted in order to provide wood pulp for export. The whole project has been a financial disaster for Ludwig, an ecological disaster for Amazonia and a social disaster for the people who flocked there for employment. The project is being taken over by the Brazilian Government and several Brazilian companies, but its future is uncertain(565-569).

The other large scale resource exploitation projects in Amazonia are those of the big mining companies. Some are underway, others are at an advanced stage of planning; the two principal minerals involved are bauxite and iron ore.

Electrical Energy in the Amazon

At present, the generating capacity and consumption of electricity in Amazonia is small. Until 1976, the installed capacity was only 458 MW, and annual consumption 1 155 GWh, 2% and 1.5% respectively of the national total(570,571). The nuclei for electrical energy consumption in Amazonia are small and, usually, separated by great distances. There is a general lack of large scale industrial enterprises which accounts for the low level of electricity demand. This has had the effect of discouraging high initial investment in generation schemes.

On the other hand, the cities have shown high rates of increase in electricity consumption, with a rise in demand for the installation of small and medium size generating units, which due to the restricted markets have tended to be oil fired(572). According to ELETRONORTE the development and integration of the region by the exploitation of its mineral and other wealth needs the support of an adequate supply of energy, "given the characteristics of its utilization as an instrument of progress. This integration and development should not be accomplished to the exclusive interest of the region, but should be part of the national development of Brazil as a whole"*(573). Such an attitude may be said to colour, significantly, the decisions concerning energy development in the Amazon region. The hydroelectric potential of the Amazon river system, considered at the level of technico-economic viability is comparable to that of the other primary sources of energy, and must be considered when trying to meet the ever- increasing needs of the

*...dados as caracteristicas de sua utilizacao como instrumento de progresso. E e sumamente importante que a integracao e o desenvolvimento da Amazonia nao sejam entendidos como de interess exclusivo da regiao.

energy markets in other regions of Brazil(574).

However, until the oil crisis in 1973, Amazonia had been little considered for its energy potential, with one notable exception. In 1965 the Hudson Institution in New York, suggested the creation of a network of Great Lakes by damming the Amazon river itself. This project was intended to open up a development area the size of the United States of America and to provide enormous quantities of hydroelectricity(575). The plan was to build a 30-50 km long dam, 30 m high at Monte Alegre. This would have produced a man-made lake greater than 1000 km long, flooding all the low river towns betweens Monte Alegre and Manaus, including Santarem, and, in addition, almost all the currently cultivated agricultural zones in the region, with the displacement of at least 100 000 people. The electrical potential was calculated at 74.6 GW(576). Not surprisingly, this suggestion was attacked from every conceivable angle. Besides the extensive environmental and cultural ramifications such a scheme would have had, the Hudson Institute was accused of attempting to :

> "...internationalise the Amazon for imperialistic purposes, of intending to settle millions of militant United States anti-white Negroes in the area, of developing the area for the United States survivors of a major thermonuclear exchange ...." (577).

Despite the attempts of members of the Institute to clarify their motives, the only comment which can be made on this scheme is that it was ludicrous.

Not only did the oil crisis have a significant effect on the energy perspective of Brazil, but it also had a considerable impact upon that of Amazonia. The principal cities of the region are supplied with electricity generated by oil-fired or diesel generators. The generating costs must cover both the actual cost of the fuel and also the cost of transporting it by boat to the consuming centres. As a result of high costs and low population density the great majority of the installed generators have capacities of between 2 and 100 kW. One possible solution to the problem of fuel costs is the substitution of diesel oil by vegetable oils, using the experience and technology of French Africa, or by increased dependence on wood and wood products. However, earlier experience with combustible solids, such as wood, did not prove to be successful. Experiments by Centrais Elétricas de Amazonia (CELETRAMAZON) collapsed in the face of erratic supply and the extremely variable price of wood. The same currently applies to Centrais Elétricas de Acre (ELECTROACRE), and had done so for the Pará Electric Company as long ago as 1920, and Manaus Tramways & Light Company in the 1940s(578). However, for the future, and on the larger scale, the main answer lies in increased use of the hydroelectric potential available(579).

The Concessionaires

There are various electrical energy concessionaires in the region, mostly associated companies of ELETROBRAS. The majority of their fixed capital is state or Federal Government owned. Centrais Elétricas do Pará (CELPA) is the state company for Pará, operating principally in Belém, and the interior of the state. Centrais Elétricas de Amazonas (CELETRAMAZON) operates in the State of Amazonas, and in the future may take over the supply to Manaus, currently in the concessionary area of the Companhia de Eletricidade de Manaus (CEM), a subsidiary of ELETROBRAS. The Federal Territories of Rondônia, Roraima and Amapá are the concession areas of Centrais

Elétricas de Rondônia (CERON), Centrais Elétricas de Roraima (CER) and Companhia de Eletricidade do Amapá (CEA) respectively. Centrais Elétricas de Acre (ELETROACRE) acts in Acre, Centrais Elétricas de Goiás (CELG) in Goiás and Centrais Elétricas de Mato Grosso (CEMAT) in Mato Grosso(580).

Hydroelectric Power in the Amazon

ELETRONORTE was created in 1973 to study and operate the exploitation of the hydroelectric power potential of the Amazon region. At the inception of the company, the Federal Government intended to develop an ambitious and impressive energy programme in Amazonia, consisting of the construction of various large scale hydroelectric power stations, with the objective of supplying part of the consumer market of North, North East and Central Brazil.

The first role of ELETRONORTE was to continue the work of the Comitê Coordenador dos Estudos Energéticos da Amazonia (ENERAM), enlarging the surveys of the Tocantins-Araguaia Basin, and resuming the studies of the rios Trombetas, Erepeurui, Vatumã, Jatapu, Cotingo and Jamari, plus all other tributaries and sub-tributaries of the Amazon(581). These surveys were very necessary. One of the reasons for the adoption of thermal generation in many areas, was that as a result of a shortage of data on the hydrology, geology, topography and cartography, hydroelectric projects could not be defined and thermal generation was the sole alternative. (It should be noted that the lower investment costs, the small transmission systems needed, the shorter installation periods and the smaller volume of works were also incentives, that is until outweighed by the rising cost of fuel)(582). There was also the financial incentive offered by the

Conselho Nacional de Petroleo, in which those concessionaires operating isolated thermal stations were exempted from payment of the Imposto Unico (see p. 61).

The projected development of the Amazonian hydraulic potential for power soon gained popularity and a number of large scale schemes were proposed, principally UHE Tucuruī, 3.0 GW (in 1974), 300 km from Belēm on the rio Tocantins and UHE Sao Felix, 1.2 GW, also on the rio Tocantins 250 km from Brasīlia. The latter is to be interconnected with the South East region(582). The inventory survey of the Tocantins- Araguaia basin gave an initial estimated potential of 18 GW,subsequently adjusted to 21 GW, and surveys of the river basins north of the Amazon river revealed 21 potential hydroelectric sites with another ten on the southern tributaries. ELETROBRAS announced that it was going to embark on "the greatest hydroelectric programme in the world"(583).

However, it was emphasised that the inventories formed only the foundation for energy planning, and less than six of the 31 potential hydroelectric sites would be initially developed before the middle of 1977(584). This was reported in 1976, and in that year, in fact, development was begun on only three sites(585).

The sites inventoried in the Tocantins-Araguaia cascade are shown in Appendix 4.

The six stations given initial priority were UHE Tucuruī; UHE Couto Magalhães, which was to benefit the population of the north of Mato Grosso and Cuiabá; UHE Sao Felix, which was to meet the needs of Brasīlia and northern Goiās; UHE Santo Antonio II, which would be the first hydroelectric power station in Roraima; UHE Samuel, to supply the city of Porto Velho; and UHE Balbina to supply power to Manaus(586). Of these six stations, only one is under construction, UHE Tucuruí, and the others are still at the project stage. Although according to the Plano 95, UHE Couto Magalhaes is planned for operation in 1986 (110 MW), UHE Sao Felix (1060 MW) for 1989 and UHE Peixe (736 MW) for 1990. It should be noted that the proposed installed capacity has been reduced considerably for all three stations, and all of them are close to the southern limit of Amazonia(587).

The journal, Mundo Elētrico, commenting on the possibility of long distance transmission at voltages up to 1 500 kv, A.C., and the possibility of inter- connections between the North and South East, and North and North East, coupled with large scale mineral exploitation in Amazonia, reported that it would require the construction of 52 large and medium sized hydroelectric power stations, by ELETRONORTE, by the year 2005 (588). But according to the Plano 95, only four are scheduled to be in operation by 1990, but the further 52 are available for expansion of the installed potential (Plano 95. p.71.)

Isolated Systems

Many of the potential hydroelectric developments in the Amazon region could, economically, supply only a small isolated market. The two that have been completed are UHE Coaracy Nunes (40 MW), on the rio Araguaia in the state of Amapá, 80 km north west of Macapá, which began operation in 1976, and UHE Corua-Una (10 MW) on the rio Corua-Una, 70 km south west of Santarem, which started up in 1978. Of these two, UHE Corua-Una is so small that it is not mentioned in the ELETRONORTE annual report of 1978. The UHE Coaracy Nunes system was able to commence operation as originally planned, in 1978, when the 13.8 kV line to the community of Ferreira Gomes was completed, by CEA, together with the Santana substation, which was connected to the cities of Macapá and Porto Santana(589).)

The isolated transmission systems proposed for UHE Couto Magalhães, UHE Balbina and UHE Samuel are currently under study, and the projects for the power stations are at various stages of development. For UHE Couto Magalhães, on the upper rio Araguaia, work has already reached the preliminary design stage, for the underground power house and other principal works. As to the other essential works, studies are in progress for the various necessary infrastructures, including the Vila Residencial (township) and the various alternatives for the construction of the airport.

UHE Samuel (216 MW), on the river Jamari 40 km south east of the city of Porto Velho in Rondônia, is being reappraised, by ELETRONORTE, on the evidence of new aerophotogrammetry data. The whole scheme is being revised, including the re-siting of the Vila Residencial. The preliminary transmission studies were completed during 1978 (590).

UHE Balbina, 146 km from Manaus, on the rio Vatumã, is urgently required to solve the problem of the costly production of oil fired electricity for the rapidly expanding city. The project was first suggested by ENERAM in 1973. It is extremely isolated and only accessible by boat up to Cachoeira Morena, 20 km downstream of the site. From there the river is only navigable by small boats or motorised canoes. However, a road access is in the process of being built. The installed capacity will be 250 MW, and the associated transmission system will comprise of 190 km of 230 kV line. The support works will include a Vila Residencial and 72 km of access road, from the BR 174 Manaus-Caracarai road. For such a small hydroelectric power station, the area to be inundated is very large, over 2 000 km^2. The cost, as estimated in 1978, was US$. 558×10^6 (December 1978 prices), including US$ 77×10^6 for the transmission system. This gives a unit cost of US$ 1 924/kW, excluding the transmission costs, which is extremely high. However, the forecast for fuel oil consumption by Manaus, in 1979, was 190×10^3 tonnes, and, if the generating park expands to meet the market purely by the addition of oil fired stations, this consumption would reach an annual value of 460×10^3 tonnes by 1990 (591).

UHE Tucuruí

History

The first reconnaissance of the hydraulic resources of the basins of rios Tocantins and Araguaia was made, in 1964, for the Bureau of Reclamation, through the Agency for International Development of the United States Department of State, by the now defunct Comissão Interestadual dos Vales do Araguaia-Tocantins (CIVAT) (Interstate Commission for the Araguaia-Tocantins Valley). Between 1968 and 1972, the Departamento Nacional de Portes e Vias Navegáveis (DNPVN) (National Department for Ports and Waterways) also made studies of the rio Tocantins, as part of a general study of interior navigation routes within Brazil(592). Conflicting reports(593) suggest that the DNPVN studies were, in fact, made prior to those of CIVAT, but it is certain that by 1972 further studies of the region had been made by ENERAM. This committee in its final report, recommended a systematic survey of possibilities to utilise the hydroelectric resources of the Tocantins basin, and the identification of those projects which would be able to meet the demand from the energy markets represented by Belém, Brasília, and part of the Centre West region, in addition to the demand represented by the proposed establishment of electro-metallurgical enterprises, and the interconnection with the CHESF system.

In response to this report, the Minister of the MME, recommended that ELETROBRAS be responsible for these further surveys, which were resumed in July 1972, and subsequently taken over by ELETRONORTE (see p.159). It inherited the responsibility for the studies of the Tocantins-Araguaia basin, and for the development of the hydraulic potential of the lower rio Tocantins, in order to meet the energy market, now specified by the city of Belém, and the heavy loads required by the proposed alumina-aluminium complex.

The work which was accomplished by ELETRONORTE at this stage included the organization of the inventory studies of a number of hydroelectric sites in the rio Tocantins basin, and the feasibility studies for the São Felix, Santo Antônio and Tucuruí schemes. These latter studies were based on aerophotogrammetry, hydrometric surveys, geological-geotechnical investigations, estimates of reservoir areas, socio-economic studies and surveys on the effects to be felt by towns, roads, forest parks, mineral resources and navigation facilities(594). The data gathered were used to make comparative studies of the various alternatives.

As a result of these studies, the site of Tucuruí was chosen as the one to best meet the requirements of the market. It had the advantages of a high hydraulic potential and nearest proximity to the market of Belém. Studies of this site, therefore, passed from the feasibility stage, to that of the basic project stage. The feasibility studies had been carried out by ENGEVIX S.A. - Estudos e Projetos de Engenharia (the technical studies), and the economic studies had been undertaken by ECOTEC - Econômia e Engenharia Industrial S.A.. Three years later, in 1975, ELETRONORTE awarded the contracts for the basic and executive design projects to ENGEVIX S.A. and THEMAG - Engenharia S.A.(595).

These further studies were follwed by more detailed investigations and included trials using a small scale model of the hydroelectric power station, and computer simulations for the optimization of the general arrangement of the works and the installed capacity. These considered the regulation of the water flow by UHE São Felix reservoir, as well as the case of UHE Tucuruī operating without upstream regulation. The studies had the secondary purpose of finding ways to improve the navigability of the rio Tocantins as far as the town of Marabá, which will be at the upper end of the Tucuruī reservoir. The stretch of river between Tucuruī and Marabá is currently impassible due to rapids.

Purpose and Market of UHE Tucuruī

The concepts behind the scheme of UHE Tucuruī have, of necessity, changed over the years. These are reflected the changes which have occurred in both Brazilian and world affairs. The underlying factors are :

i. the presence of a great hydraulic potential in the rio Tocantins basin,

ii. the presence of large reserves of bauxite in the Trombetas and Paragominas regions,

iii. a small domestic and industrial market for power in the city of Belém, and

iv. a very large industrial market 3 000 km distant, in the South East region of Brazil.

In 1973, Japanese engineers, from the Electric Power Development Company Limited proposed, to the then Governor of the state of Pará, Fernando Guillon, that a large hydroelectric power station should be constructed on the rio Tocantins. This station was to supply the electrical energy necessary for a future aluminium smelter, for which permission for construction on the rio Trombetas had been sought. The proposed smelter was to have an output capacity of 500 000 tonnes of aluminium per year, with room for possible expansion up to 10^6 tonnes per year. Preliminary studies for the scheme had estimated a possible installed capacity of 3.0 GW, thirty times greater than the total installed capacity then existing in Belém(596).

An agreement was signed between the Brazilian Government, through the CVRD, and a consortium of Japanese aluminium enterprises, represented by the Light Metal Smelter's Association. This resulted in the formation of Aluminio Brasileiras S.A., ALBRAS, to produce aluminium, and Aluminio do Norte S.A., ALUNORTE, which was to make alumina. The two processing plants were to be located in Baracena, close to Belém, and were to require an investment of approximately US$ 1.4×10^9.

At the end of 1973, the Secretaria Geral of the MME, Benjamin

Dias, confirmed that ELETROBRAS was already executing detailed studies on the available hydraulic energy in the Tocantins-Araguaia basin, where, it had been estimated, there was an hydraulic potential of the order of 7 GW(597). By early 1974, it was announced that the first large Amazonian hydroelectric power station would be constructed on the rio Tocantins, with an installed capacity of 2.5 or 3.0 GW. It would begin operation in 1981, and would supply power to the aluminium smelter which was being planned for a site near to Belém.

During this same period, the President of ELETRONORTE, announced that the new techniques being developed for long distance transmission would make it both technically and economically feasible to develop the potential of the Amazon region, in order to supply the industrial South East with electricity. In so doing Brazil would be following the example of the USSR, which was planning to introduce transmission lines up to 2 400 km long.

The hydroelectric power station proposed at Tucuruī would be able to ensure a sufficient supply of energy for a 500 000 tonne smelter and still have sufficient additional capacity to provide power for transmission to the central region of Brazil. This would free the power stations of CEMIG and FURNAS, which were supplying this region, so that they could instead meet the growing demand of the state capitals of São Paulo, Rio de Janeiro and Belo Horizonte(598).

By mid-1974, the stated aim of UHE Tucuruī was to facilitate the development of the bauxite reserves present in the region, and thus to transform Brazil into a great exporter of aluminium products(599).

Early the next year, work on the dam site was speeded up so as to guarantee the entry into operation of the power station in time to meet the initial requirements of the aluminium smelting complex from the outset. At this stage, the construction of the final work camp was underway, and the access roads, airport and the dock, for the unloading of construction equipment, were close to completion. It was planned to start work on the first phase of the river diversion in the immediate future(600).

However, this need for urgency was soon superceded by concern at the escalating costs of both the hydroelectric and aluminium schemes, and it was consequently suggested that the MME should look into the high estimated cost of the electricity to the proposed ALBRAS smelter at Baracena. In the processing of bauxite to aluminium, one of the major costs is that of the electricity used. If UHE Tucuruī was going to be an expensive power station to operate, this would be reflected in a high cost for its electricity, which could make the operation of the proposed aluminium smelter economically unattractive(601).

The concern of ALBRAS about the electricity costs was clearly understood by ELETROBRAS, because in the 30th issue of its journal "Revista Brasileira de Energia Elētrica", the article on UHE Tucuruī stated that the primary objective of the hydroelectric power station was to meet the power requirements of Belēm, the projected increased consumption by eletro-metallurgical enterprises in the region, (there was no specific mention of aluminium smelting), and, additionally, to supply the future inter-connection with the CHESF system(602). The ALBRAS smelter was no longer considered as the primary market for UHE Tucuruī. Perhaps it was already suspected, as in fact turned out to be the case, that the aluminium enterprise would fall through.

Whilst ELETRONORTE was studying the economic viability of the exploitation of the hydraulic potential in the Amazon region, ELETROBRAS was considering methods of using the power produced to supply the industrial South East. As the distances involved are greater than 1 500 km, ELETROBRAS was considering transmission at extra-high-voltage. With this possibility, UHE Tucuruī became to be regarded as having a significant role in the national integration policy of the Brazilian Government, in which the ELETRONORTE system would be linked to those of the North East, Centre West and South East regions(603). This plan was later modified to exclude the North East-South East interconnection, as it was considered that there was insufficient hydrological diversity between the two regions, especially when there will be no surplus power to send to the North East from the industrial South East(604).

A statement was issued, at this time, by the President of ELETROBRAS, to the effect that UHE Tucuruī would be built independently of the ALBRAS construction, using national resources. This statement echoed the decision of the Brazilian Government to construct the hydroelectric power station in order to meet the energy needs of the North and North East regions, which were considered to have expanded sufficiently to justify a new major source of power. No formal agreement had been made, with the Japanese partners of CVRD in the ALBRAS consortium, for the investment of US$ 700×10^6 in the smelter. A letter of intent had been signed on the occasion of a visit to Brazil of the Japanese ex-Prime Minister, Kakuei Tanaka(605), but that was all. In 1975, UHE Tucuruī was viewed as an example of governmental intent with respect to the plans of ALBRAS to exploit the bauxite reserves in Paragominas as opposed to

Trombetas(606). In 1976, it was announced that the Japanese had withdrawn from the scheme, on the grounds that the size of the proposed smelter was too large(607), but despite this, it was also announced that the turbines and generators for UHE Tucuruī were to be provided by a Japanese consortium, comprising Toshiba, Hitachi, Mitsubishi Heavy Industries, Mitsubishi Electric Corporation and Fuji Electric Company, with Toshiba acting as the managing company. It was also expected that the Brazilians would receive a US$ 300x10^6 loan from Japan, in return for purchasing the equipment(608). Nevertheless, this was the last that was heard of Japanese involvement in the schemes.

By late 1976, it had become necessary to propose additional justification for the Tucuruī scheme. In a statement from the Ministry for Transport it was declared :

> "The geographical position, the natural conditions, the energy potential, the wealth already in the Tocantins-Araguaia basin, and their proximity to Brasīlia, are factors which predispose the rios Tocantins and Araguaia for development into first class waterways, with more than 3 000 km of navigable river serving the states of Mato Grosso, Goiás, Pará and part of Maranhão"*(609).

Submersion of the rapids at Itaboca by the Tucuruī reservoir will remove the principal obstacle to navigation of the rio Tocantins as far as Marabá. However, despite the optimism of the Transport Ministry, the project designs, published in 1976, by the consulting engineers, contained no designs for navigation locks(610).

---

* "A posição geografica, as condições naturais, o potential energético, as riquezas já presentidas em sua bacia e a situação em relação a Brasīlia são os fatores que credenciam os rios Tocantins e Araguaia a serem transformados em hidrovias de primeira classe, com mais de 3 mil de kilometers de aproveitamento viário, servindo aos Estados de Mato Grosso, Goiás, Pará e parte de Maranhão".

Although President Ernesto Geisel inaugurated the principal works of UHE Tucuruī in February 1977, the purpose of the hydroelectric power station had still not been clearly defined. At that time, it was expected to start generating at the end of 1981, with the intention of supplying power to the ALBRAS aluminium complex in Belēm (despite the fact that the Japanese had withdrawn from the project). In addition, it had been decided that the power could be used to facilitate exploitation of the rich deposits of iron ore in the Serra do Carajas, a mountain range to the south west of Tucuruī, by providing the power for an electrified railway(611).

It was not until ELETRONORTE published a summary report of the Tucuruī scheme that any clear definition of the market for its power was outlined. This comprised

i. the interconnected system of Belēm,

The electricity from UHE Tucuruī will be distributed to the town of Belēm by CELPA, as well as to the 14 towns and villages in the north eastern region of the state, which are already interconnected with the Belēm system.

ii. the Northern Region of Goiās State,

CELG will be responsible for the distribution of the electricity to some of the more important towns in the north of Goiās, including Tocantinopolis and Araguaīna.

iii. the industrial projects.

By 1977, two major industrial projects had been identified within the UHE Tucuruī area of influence. These were bauxite processing and iron ore mining.

The enormous reserves of bauxite in the rio Trombetas basin, and the smaller reserves near the town of Paragominas are estimated at over 3×10^9 tonnes. Exploitation of these reserves, originally suggested by the Japanese was intended to be the major use of the power from UHE Tucuruī and, in 1977, it was believed that alumina and aluminium projects would be shortly established. Processing of the bauxite locally is still planned, but an actual scheme has not yet been finalised.

The estimated iron ore reserves in the Serra dos Carajas were estimated at 18×10^9 tonnes in 1977, which represents the largest concentration of good quality iron ore in the world. It is of excellent quality, with a metallic iron content of 66%. In order to exploit these reserves, the Brazilian Government created a subsidiary of CVRD, the Amazônia Mineração S.A. (AMZA). It is responsible for the mining of the ore, and for its transportation by an 887 km long electrified railway, from the mine to the deep water port at Itaqui in the state of Maranhão. ELETRONORTE was supposed to be responsible for the supply of power from UHE Tucuruī to the mine and to part of the railway. The remainder of the railway's demands were to be met by CHESF. Although exploitation of the iron ore has begun, the building of the railway has not yet started(612).

iv. the interconnection with CHESF

The electrical systems of the North and North East regions will be interconnected through the Imperatriz sub-station (see p.274)(613), but, as a result of the delay of start of operation of the hydroelectric power station, the interconnection is to be used initially to supply the city of Belém with electricity from the CHESF system.

Justification of the UHE Tucuruĩ Scheme

The various proposals for the scheme have revolved around the existence of the large mineral resources which lie within the area of influence of UHE Tucuruĩ. Many of the deposits have been mapped in detail, and only require the establishment of an energy and transport infrastructure to enable the exploitation to proceed. The mining itself does not consume large quantities of power, but the mineral processing industries, using electro-metallurgical methods for the production of aluminium and nickel, are sufficiently energy intensive to justify the construction of a large hydroelectric power station(614).

Another company, Mineração Vera Cruz S.A., has been considering the exploitation of the Paragominas deposits using power to be supplied by UHE Tucuruĩ. According to ELETRONORTE, this has opened up the possibility of producing ferro-manganese and other ferrous alloys, as there are appreciable reserves of manganese in the Serra dos Carajas region. Although these additional uses of the power from UHE Tucuruĩ may be available, the market and power balance forecast for the hydroelectric power station prepared by ELETRONORTE, in 1977, assumed that only the ALUNORTE/ALBRAS and AMZA projects would be fully operational by 1988.

From tables VI.i and VI.ii, it would appear that approximately half of the power produced is intended for the CHESF market, with only a quarter for the aluminium enterprises and an eighth for the city of Belém. This is a particularly interesting forecast of the the

Table VI.i : Market Forecast for UHE Tucuruī

	Power MWav	Peak Demand MW
CELPA	218	398
CELG	6	11
ALUNORTE	17	24
ALBRAS	571	584
AMZA	43	72
CHESF	1 000	1 000
Total	1 855	2 089

Table VI.ii : Power Balance

	Power MWav	Peak Demand MW
Market	1 855	2089
Transmission losses*	55	66
Reserve(1 unit)	-	245#
Total Requirements	1 910	2 400
Available at Tuc.	2 090$	2 940#
Surplus	180	540

* Approximately 3%

Under minimum head

$ Firm energy, Tucuruī reservoir only

Source : Anon "Sistema Tucurui", ELETRONORTE, Brasilia, 1978.

distribution of energy consumption within the market, as the principal consideration in the planning of UHE Tucuruī was primarily to meet the needs of the aluminium enterprises and the city of Belém. It would appear that the eventual role of the hydroelectric power station will be quite different from the one originally intended.

The situation has now arisen where a large (4 GW) hydroelectric power station is under construction, and, as yet, the market for its power has not been properly identified. This has arisen a result of the initial haste with which the project was undertaken. There is little doubt that a suitable market for the power can be created, if adequate financing for the possible aluminium projects can be found. However, if no industrial market is established, there will be a considerable surplus of available power.

Although there has been no finalisation of any bauxite processing schemes, most of the published reports still claim that the bulk of the power from UHE Tucuruí will be used for such processing. Even in mid-1978, when the project completion date for UHE Tucuruí had been delayed, the President of ELETRONORTE, Raul Garcia Llano, was forced to admit that the hydroelectric power station would still enter operation before the ALBRAS/ALUNORTE projects. At that time, some US$ 200×10^6 had been injected into the hydroelectric scheme, as it was, and still is, regarded as a priority project by the Brazilian Government, because of the importance attached to the power which it will be able to supply to the aluminium projects which, have been estimated, will consume 5 TWh per year(615).

In 1978, although nothing had been signed, the aluminium projects were considered as having been launched, despite no basic plans having been prepared then, or subsequently. The September 1978 report in Mundo Elétrico reiterated the supposition that the principal beneficiaries of the UHE Tucuruí power would be the ALBRAS/ALUNORTE complex in the metropolitan region of Belém, the Carajas project and its railway electrifiction, and also the North East of Brazil(616). The September issue of International Construction, in the same year, reported that the construction of UHE

Tucuruī was "going hand-in-hand" with the development of the aluminium industry in Belém. According to this report, two major processing plants were "under way" near Belém, and would be supplied with power from UHE Tucuruī. The costings for the ALBRAS smelter were estimated at US$ 1.6x10^9 (1978 prices), with 49% of this sum apparently being supplied by Japanese interests. The projected initial output of the smelter was set at 38 000 tonnes per year, in 1981, and was expected to rise to 265 000 tonnes per year by 1985, when it was to employ about 8 000 persons(617).

In 1978, Brazil was importing 120 000 tonnes per year of refined aluminium, but it was expected that, on completion of the ALBRAS smelter, there would be a surplus of aluminium on the Brazilian market. In order to increase the home demand for aluminium, a research programme was initiated to study the problems of creep, corrosion and welding of aluminium, with a view to using it as a substitute for copper, a metal of which Brazil has little(618).

Early in 1979, a new name entered the scene, when the Grupo Ludwig signed an agreement with the DNAEE, ELETRONORTE and CHESF, stating the intention of the group to use the energy from UHE Tucuruī for the fabrication of primary aluminium at a smelter to be built in the state of Pará. The planned initial capacity of this smelter was to be 150 000 tonnes per year, with the possibility of doubling this capacity in the second phase(619). This has no doubt fallen through with the collapse of the Ludwig Amazonian Empire(620). By the third quarter of 1979, it had become obvious that the construction of UHE Tucuruī was well behind schedule, due to lack of finances, and that the ALBRAS project for a, now, 80 000 tonne smelter uncertain, with a result that alternative projects were being planned for the beneficiation of the Trombetas and Paragominas bauxite(621). In 1979, with the further rise in OPEC oil prices, non-oil related energy sources were given a high priority in the Brazilian Government spending, and further funds were injected into the Tucuruī scheme. The use for its energy was still not clearly defined, although it was suggested that it would be used to supply a Trombetas bauxite-alumina-aluminium complex to be managed by CVRD, and the iron ore mining project at Carajas(622).

In 1980, the Minister of the MME, Cesar Cals, injected new life into the project, by suggesting that the second phase of the project, with its additional 2.74 GW of installed capacity should be brought forward by some years. This was intended to satisfy a projected demand at the Carajas mining projects of approximately 6 GW, (the total installed capacity of UHE Tucuruī would be 6.7 GW(623)).

Despite this optimism, it was apparent, during a visit to ELETRONORTE in March 1980, that plans for the second phase of the hydroelectric power station would not be implemented until 1990-93, and it is not mentioned in the Plano 95. During the visit, it was said that the market for the UHE Tucuruī power was considered primarily to be the traditional market of Belêm and the surrounding towns, and the industrial market close to Belêm, which is was still hoped would be created by the establishment of an aluminium industry(624).

Other aluminium companies, such as C.B.A., have recently shown some interest in processing the bauxite in the region(625,626), and Alcoa Aluminio, wholly owned by Alcoa of the USA (68%) and Hanna Mining of Ohio (32%), signed an agreement with the Brazilian

Government, on 25 June 1980, for the development of an alumina and aluminium plant, in the state of Maranhão, using bauxite from Trombetas. The annual capacities of the two plants were set at 500 000 tonnes of alumina, and 100 000 tonnes of aluminium(627). It is proposed to site this complex at São Luis, some 845 km distant from Belém, and approximately 450 km from Imperatriz, where the ELETRONORTE system connects with the CHESF system. Thus the Alcoa complex will receive the power from UHE Tucuruī indirectly through the CHESF system.

It appears reasonable to presume that the processing of bauxite in São Luis will preclude its being processed in Belém. This being so, it would cut out part of the direct industrial market for UHE Tucuruī's power.

Despite eight years of proposals for aluminium smelters and the signing of many agreements, in order to justify the construction of this very large Amazonian project, the only market for its electricity is that of metropolitan Belém, and the interconnection with the CHESF system. With the current slump in the world aluminium market there is little likelihood that the position will change in the near future(628).

CHAPTER 7

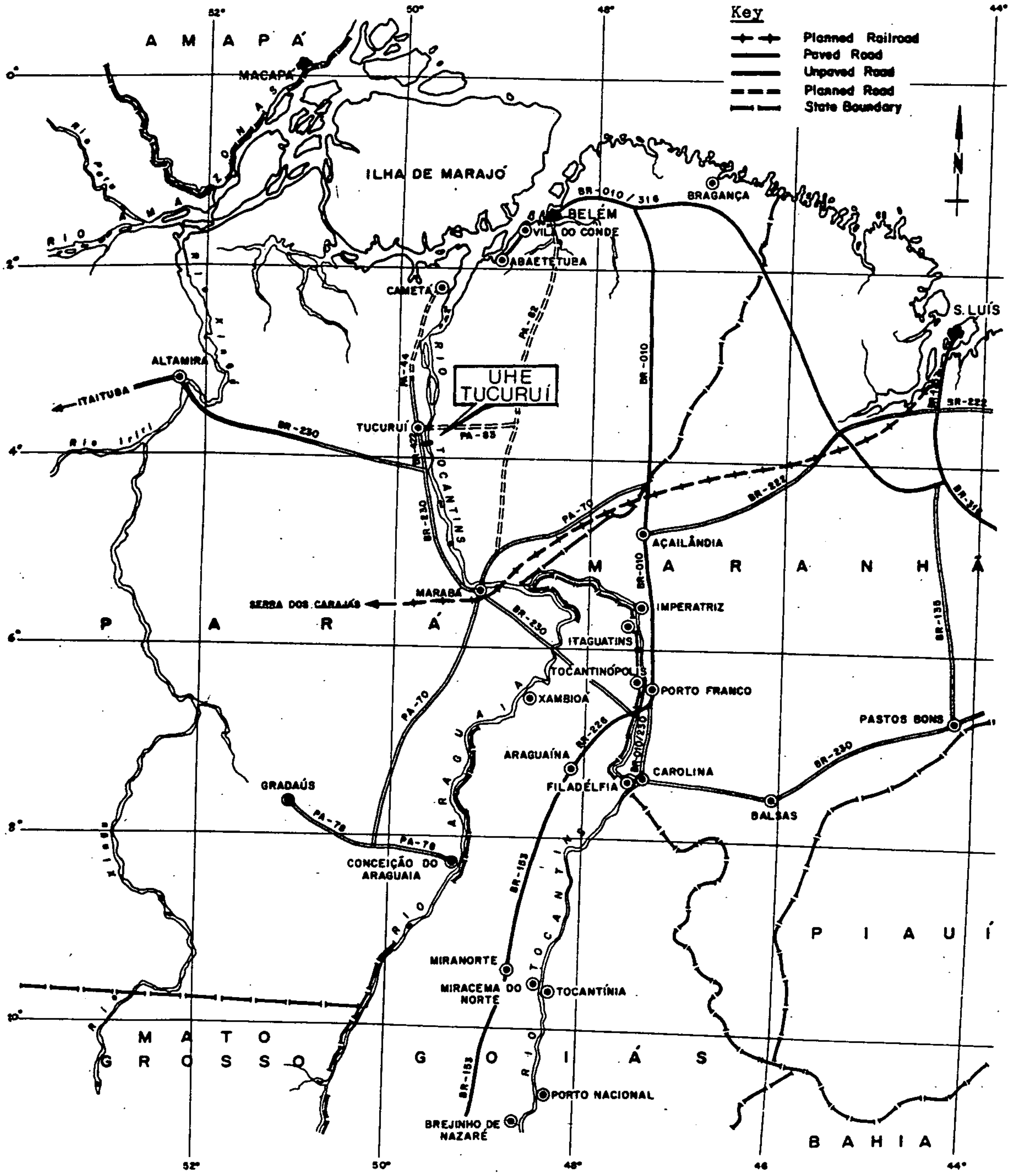
UHE Tucuruī

Position and Access

The Tucuruī hydroelectric project is situated at latitude 3 °45'S and longitude 49 °41'W, on the rio Tocantins, in the state of Parã, approximately 7 km upstream of the old town of Tucuruī. It is 300 km from Belēm, which is the most important town within its area of influence. The site is extremely isolated, and was, until recently, without any social infrastructure. The nearest road is the Transamazonica (BR 230), an unpaved highway which connects with the paved Belēm-Brasīlia highway at Estreito on the rio Tocantins. From Estreito it travels in a north westerly direction until it reaches the lower rio Araguaia, where crossing of the river is effected, upstream of the town of Araguatins, by means of a raft. The road then follows the course of that river until its confluence with the rio Tocantins at Marabã, and then onto Jatobal, where it proceeds in a westerly direction to Altamira (see figure 7.1).

In order to create road access to Tucuruī, ELETRONORTE constructed an extension of the unpaved road from Jatobal to Tucuruī, a distance of 100 km, but, due to the climate, this is impassable for six months of the year. The Departamento de Estradas do Rodagem do Parã (Parã Highways Department) is constructing a new road, the PA82, from Belēm to Parã and ELETRONORTE is to build an access road, the PA83 from it to Tucuruī. Construction and maintenance of these access roads is solely the responsibility of ELETRONORTE, as the company is responsible for all the infrastructure for the hydroelectric power

Figure 7.1 : Map of the Location of UHE Tucurui



Source : ELETRONORTE "Usina Hidreletrica de Tucurui - Projeto
Basico, 1976.

project(629).

There is good river access to the site and, with the completion of unloading facilities and the creation of a small port, the bulk of the equipment and supplies will arrive by barge from Belém. The journey takes from a minimum of 16 hours to an average of two days(630). The road access can only be used for the very heaviest equipment, and even then for only half of the year. For personnel and small equipment access to the site is by air, and ELETRONORTE has built a small aerodrome (cryptically described as being the size of a football pitch(631)), complete with tarred runway, control tower and fire-fighting equipment. The route from Belém is plied by a small privately owned air company, VOTEC, flying 20-seater 1943 Dakotas, and by the São Paulo state company VASP. It was rumoured during 1980 that a jet-liner service was to be established between Tucuruí and Rio de Janeiro, but the available facilities may preclude this as the 2 km long runway terminates in the tall trees of the tropical jungle.

The isolation of the site cannot be stressed too greatly. It is in the heart of the Amazon jungle with distances from traditional centres of supply of industrial materials being 2 850 km from São Paulo, 3 250 km from Rio de Janeiro and 2 250 km from Recifé.
The bulk of contracting plant, such as earth movers, cranes and lorries, and construction materials such as steel and cement are taken by boat to Belém, and then transferred to barges before travelling the final 300 km up the rio Tocantins to Tucuruí. The time factor involved is great, and it can take months for essential supplies to reach the site. This not only includes the construction materials, but also foodstuffs, clothing, stationery, cars, buses, petrol, oil, in fact every possible requirement for a town of 26 000

people and a large construction site.

When the original site surveys were undertaken, the original town of Tucuruī had a population of approximately 3 000. That number has now swollen to 10 000 as more people have flocked to the area as a direct result of the construction activities. In addition, a new town has been built by ELETRONORTE to house of 26 000 workers and families directly connected with the project. Unlike the old town (see p.265), this new town is supplied with all the necessary infrastructure required.

The Site

As noted earlier, the construction site not only includes the civil structures for the hydroelectric power station but also the new residential town, a port, an aerodrome and social facilities. All of it is owned, operated and constructed by ELETRONORTE, which is therefore affectionately referred to as 'Mama' by senior officials(632).

The New Town

A small pioneer village, consisting of 120 houses, was constructed, as well as a hostel, a boarding house, and first aid facilities to accommodate the ELETRONORTE staff involved in the building of the residential town and the initial construction of the dam(633).

Today, the town comprises three "villages", one of permanent houses, and two of temporary housing, called Temporaria 1 and 2. These latter two incorporate prefabricated wooden houses which can be dismantled once the power station is complete. The residential town was planned to accommodate a maximum active labour force of 10 000, and their dependents – a further 25 000(634). By March 1980, ELETRONORTE had built 6 500 houses in addition to the hostels which were housing 14 000 workers, sharing six to a room.

The houses are all supplied with free electricity, hot and cold running water, a separate bathroom and a sewage disposal system, but there is a hierarchy in the degree of luxury available to the personnel according to their position within the companies operating on the site.

Two hospitals have been constructed, with a total of 245 beds, and a complement of 44 doctors, all specialists. There are nine schools, catering for 6 000 pupils. The two senior schools also cater for adults; at the High School classes are held for adults in the evenings and at the Professional School students can learn technical skills such as general building, road building, soil mechanics and also business administration. The site has a resident psychologist to help retarded children.

Each village is supplied with a commercial centre and a recreation centre, with facilities for a number of sports. Shows are frequently put on to entertain the inhabitants, including visits by nationally known celebrities. The two supermarkets are stocked with a wide range of goods, all of which have to be imported into the area. There are six "restaurants", but again the standard depends very much on the personnel being catered for. The new town sports two banks and an ecumenical centre, which is used for worship by all denominations at separate times.

Worldwide telephone links have been established and there are two telephone exchanges with the locals being served by four public telephones. Communications within the town include tarred roads on which operate 35 local buses. In addition, there are 80 site buses to take the workers out to the dam site, together with 154 VW sedans, 35 kombi vans, 28 "simple" lorries, five aeroplanes, and one helicopter. All these vehicles are in fact leased and not owned by ELETRONORTE, but they all still had to be brought to the site by barge.

It must be emphasised that the establishment of the infrastructure for this town has been the sole responsibility of ELETRONORTE, and the need for such facilities in this isolated location has been instrumental in raising the costs of this already expensive project. It must also be reiterated that everything – from building materials, through vehicles to foodstuffs has to be brought in from at least 300 to 3 000 km away.

Additional facilities in the new town of Tucuruī include a water treatment plant, sewage disposal facilities and a 32 MW oil-fired power station – to supply electricity to the town and construction site(635).

The Old Town

The situation of the old town of Tucuruī, 7 km downstream from the construction site is quite different. The population of this town was only 3 000 at the start of the construction of the dam. A conservative estimate now puts it at 10 000, with new people having been attracted to the area by the possibility of earning money as petty traders or from employment connected with the setting up of a new town and the construction site. Some have managed to gain employment, but most eke out a living by offering services to the inhabitants of the new town.

The facilities in the old town are poor, the roads are untarred, most of the houses are wooden shacks, and those on the river banks suffer from flooding. Open drains run through the streets, rubbish lies uncollected, and scavenging dogs and goats roam free. Some buildings are supplied with electricity from small, private generators, but there is no piped water or sewage disposal. Water is collected from the river in cans(636).

The townspeople of old Tucuruī soon became aware of the relationship between the new town and ELETRONORTE, and, in turn, they now look to the company for help. ELETRONORTE has already supplied milk and food, housed some people, and even built graveyards for the town. In 1980, the mayor informed ELETRONORTE that the old town was without running water, on the assumption that it was the company's responsibilty to rectify the situation(637). To date, ELETRONORTE has aided in the provision of vocational training in subjects such as carpentry, driving and technical skills, it has operated vaccination programmes and trained women in basic hygiene and household management.

The Port

The port at Tucuruī is one of the more important facilities provided by ELETRONORTE. As the majority of supplies reach the site by river, comprehensive unloading facilities are necessary and, eventually, two docks will be established, one for use by ELETRONORTE for the unloading of heavy goods such as turbines and other specialist equipment, and the other for use by the civil constructors, Camargo Corrêa, for offloading construction materials.

The port is situated on the left bank of the rio Tocantins, 5 km downstream from the construction site, and 2 km upstream of the old town. As of early in 1980, the facilities consisted of a single dock with two cranes for unloading, but handling facilities were expected to be improved by autumn of that year by the addition of a 50 t crane(638).

The dock for use for discharge of materials will be used mainly for the unloading of materials, especially agglomerates, such as cement and ashes, and steel and wood. It is estimated that at its period of peak use some 1.5×10^6 t of equipment and 40 000 t of cargo will be handled per month(639). One of the problems encountered in planning the dock was how to cope with the fluctuating levels of the river throughout the year. A floating structure was chosen, comprising a floating quay of reinforced concrete, connected to the landing area by means of a metal bridge to a ramp. This arrangement can cope with wide variations of up to 17 m in the river level. Depending on the level of the water, the quay will be placed in one of four positions, each one corresponding to a prepared rock landing. It will be anchored by large ties and movement between landings will be aided by winches operating steel cables attached to the ends of the ties. It is expected that the quay will be moved four times a year with the upper landing being used only at times of exceptional flood.

The special equipment dock will be equipped with a concrete ramp of maximum inclination 4%, in order to permit easy offloading of laden lorries. During unloading the barges will be stabilised by a system of anchorage or ballasting, and extra heavy loads will be unloaded from the fixed dock using a 250 t crane.

Barge transportation of equipment and materials from Belém to Tucuruí is not an easy business. They have to travel upstream against not inconsiderable river flows, the reported maximum in 1980 was 63 000 m^3s^{-1}, and have to meet certain conditions. In the dry season, the restrictions on draught of the barges is 1.5 m on the journey between Cametá and Tucuruí. However, the barges have to be large enough to be stable during loading and unloading. The top-deck structures have to be reinforced to be able to withstand a maximum distributed load of 350 t(640).

Project Data

The isolation of the site of Tucuruí has created enormous difficulties in attempting inventory and feasibility studies of the site. Much of the data obtained has been inadequate and even inaccurate, with the resulting need to modify plans even in the execution stage. For example, the statistical 10 000 year flood used to calculate maximum river flows was exceeded in 1980 by 9 000 m^3s^{-1}. Similarly, the underlying geology was incorrectly assessed, necessitating foundation excavations for the main dam to be increased by a further 30 m(641).

Hydrometeorology

The hydrographic basin of the rio Tocantins, see figure 2.3, extends some 2 500 km from its source to its mouth. It is located almost entirely between parallels 2° S and 18° S, and longitudes 46 W and 55 W. The basin is enlarged by the presence of the rio Araguaia which extends in a south-north direction, almost parallel to the rio Tocantins, and the confluence of the two is about 50 km upstream of Marabá and 250 km upstream of Tucuruí. The basin includes part of the states of Goiás, Mato Grosso, Pará, Maranhão and the Distrito Federal.

The rio Tocantins rises in the Planalto de Goiás, in the vicinity of the Distrito Federal, and the total drainage area of its basin is 767 000 km^2, of which 382 000 km^2 correspond to the Araguaia basin. The topographic relief of the basin is monotonous, the altitude varying only between 200 and 500 m, except in the immediate region of the headwaters, where it rises to 1 000 m. Below Tucuruī the altitude is always less than 100 m(642).

The rio Araguaia rises in the Serra do Caipó, at an altitude of 850 m, close to the headwaters of the Paraná and Paraguaī basins. Its course comprises stretches of gentle slope cut by falls and rapids. In its central stretch is the large Ilha do Bananal, the largest freshwater island in the world, occupying an area of some 350 km by 80 km(643). For the main part it is extremely boggy, and it naturally regulates the river flow by acting as a sponge.

Climate

The Tocantins basin may be divided into two climatically homogeneous regions. To the North of parallel 6° S, including the project site, it is covered with tropical moist forest, seasonal in the south and evergreen equatorial in the north(644). The mean total annual rainfall is greater than 2 000 mm. The southern two-thirds of the Tocantins basin, south of 6°S, lies in the seasonally dry savannah uplands of Central Brazil, and is important for the regulation of the hydrographic regime of the basin. The mean annual rainfall varies between 1 500 mm and 1 600 mm, all falling between the harsh dry seasons which may last up to six months. The Itacaiunas basin, a sub-basin of the Tocantins, upstream of the project site, lies in a wet tropical belt and experiences annual rainfalls of up to 3 000 mm, distributed throughout the year, with a slightly drier season of only one to three months duration(645).

There is little temperature variation in the Tocantins basin, with values averaging 22 °C in the south and 27 °C in the north. The yearly maximum and minimum differ by no more than 14 °C. The relative humidity averages 76% over the whole basin, reaching a maximum of 85% in the equatorial zone north of parallel 6 °S(646). The evaporation is high, averaging a mean annual value of 825 mm in the region of Tucuruī, and rising to 1 009 mm near Imperatriz(647).

Mean Monthly Discharges

Hydrological studies of the Tucuruī used basic data from seven fluviometric stations, but only one of these stations, Porto Nacional, established in 1949, has been in operation for any lenghth of time. Calculations of the discharges from Tucuruī were based on the historic data available from this station, supported by the more recent records from the other stations. However, scarcity of flow data meant that simulation modelling was necessary in order to calculate the mean monthly discharges from Tucurui and the firm energy.

The mean monthly discharge was calculated as 9 000 m^3s^{-1}, and using statistical methods the design floods for Tucuruī, were 51 000 m^3s^{-1} for the diversion discharge, using a recurrance interval of 25 years, and 100 000 m^3s^{-1} for the spillway discharge, corresponding to a 10 000 year flood. In fact, the diversion discharge had already occurred once since 1949, when a flow of

51 100 m^3s^{-1} was recorded at Porto Nacional in 1957. However, this value was exceeded by 9 000 m^3s^{-1} in 1980, when the diversion structure, which had already been built, successfully withstood the flow. As a precaution, its height was subsequently raised a further 3 m(648,649).

Area of Influence of UHE Tucuruī

The Tucuruī system consists of the hydroelectric power station of UHE Tucuruī and five load points - Belém, Vila do Conde, Tucuruī, Marabá and Imperatriz(650).

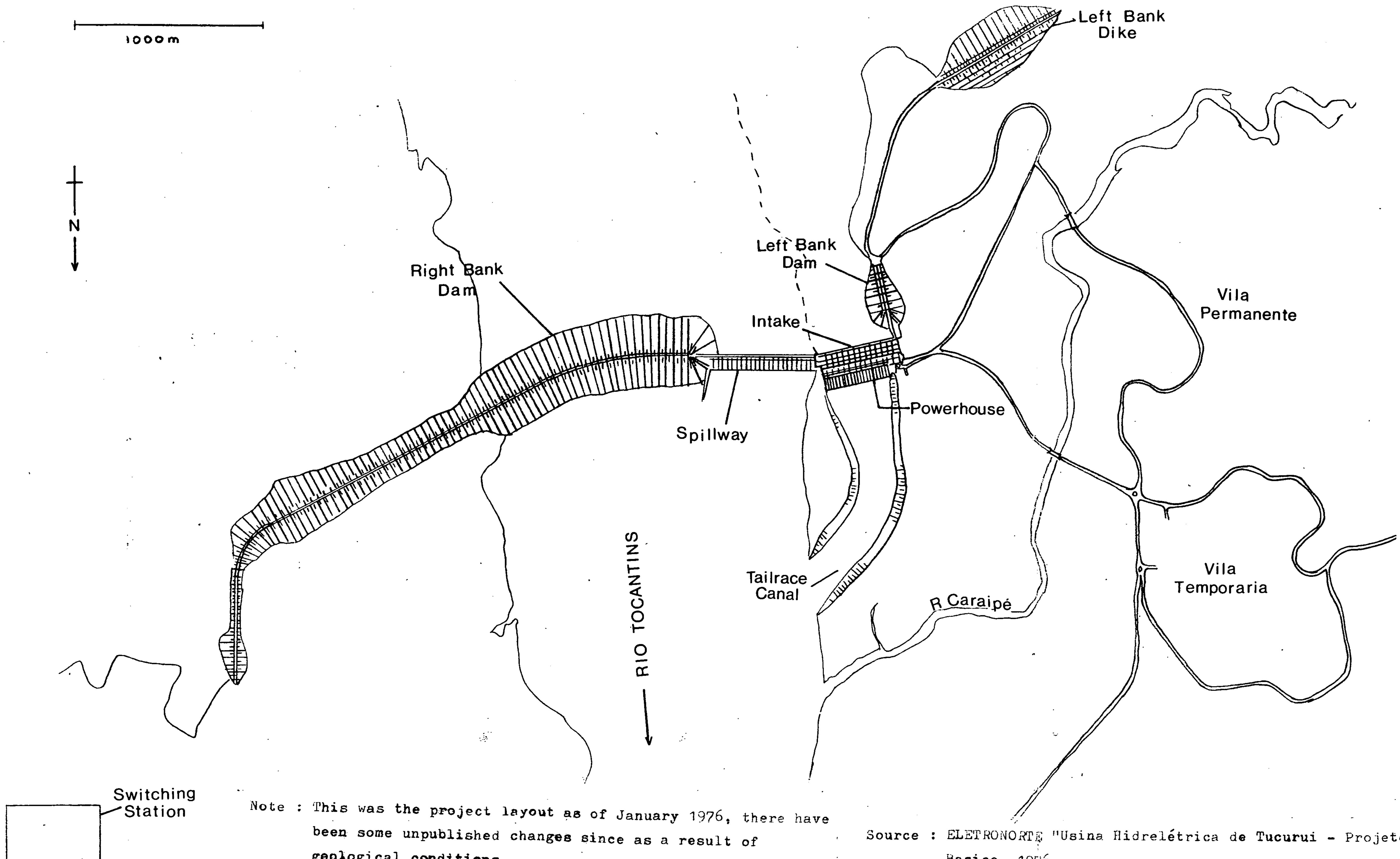
Belém

This port at the mouth of the Amazon river, capital of the state of Pará, has 935 000 inhabitants, and is one of the major cities in Brazil. It was first developed for the export of rubber, and was the port of entry for the whole of the Amazon region. All economic activity which occurred in the region was reflected by the city's development. However, its privileged position was lost when Amazonia was opened up by highways giving direct access from the South East through Brasīlia. In recent years, its development, in relative terms, has been inferior to that of other cities, but the proposed aluminium projects, and other industrialization, are expected to bring a new surge of economic activity to the city and surrounding towns, such as Bragantina and Salgado.

Vila do Conde

The proposed alumina/aluminium complex of ALUNORTE and ALBRAS was originally to be situated at Barbacena, just outside Vila do Conde. In addition to the industrial development, it was intended to

Figure 7.2 : UHE Tucurui - project layout



Note : This was the project layout as of January 1976, there have been some unpublished changes since as a result of geological conditions.

Source : ELETRONORTE "Usina Hidrelétrica de Tucurui - Projeto Basico, 1976.

install an urban nucleus for about 18 000 inhabitants, and a modern port able to handle boats of up to 35 000 t dead weight. The port would have to be able to handle supplies and equipment for the aluminium complex and also export aluminium, produced by ALBRAS, and bauxite, mined by Mineração Vera Cruz S.A. (a CVRD/RTZ consortium) in the Paragominas region(651).

Tucuruī

The load area of the two towns of that name will be supplied with power by CELPA (Centrais Elētricas do Parā), from the auxiliary supplies of the hydroelectric power station. It is expected that the load area will grow continue to rapidly during the construction phase of UHE Tucuruī, but it is difficult to forecast what the load growth will be once the work is concluded.

Marabā

Electricity distribution to this load centre will not be for the city alone, but will include the provision of supplies to AMZA when it begins exploitation of the iron ore deposits in the Serra dos Carajas. Marabā, an important regional nucleus in the state of Parā, is the principal centre for production of the castanha de Parā (Brazil nut). It is also the subject of an ambitious project to rebuild the town on higher land to alleviate the effects of flooding, to provide accommodation for the labourers expected on the Serra do Carajas projects and to act as an overspill to the state of Maranhão. It is expected that the 1976 population, of 55 000, will be increased by more than fivefold once exploitation of the Carajas deposits begins(652). The town is situated on the left bank of the rio Tocantins a little upstream of the tailwaters of the planned Tucuruī lake. It is currently served by the Transamazonica highway but, once the reservoir is filled, it will also be accessible by river from Belém. Together with the construction of the proposed AMZA railway, the improved communications with the area are expected to further stimulate the growth of the town(653).

In recent years, there has been considerable social tension in the area due principally to land tenure disputes between powerful landowners and small scale farmers. This has resulted in imprisonment of farmers and demonstrations and riots in the streets. The town's, now swollen, population of 100 000 (1980) are reported to live in a climate of violence and "easy" money(654).

Imperatriz

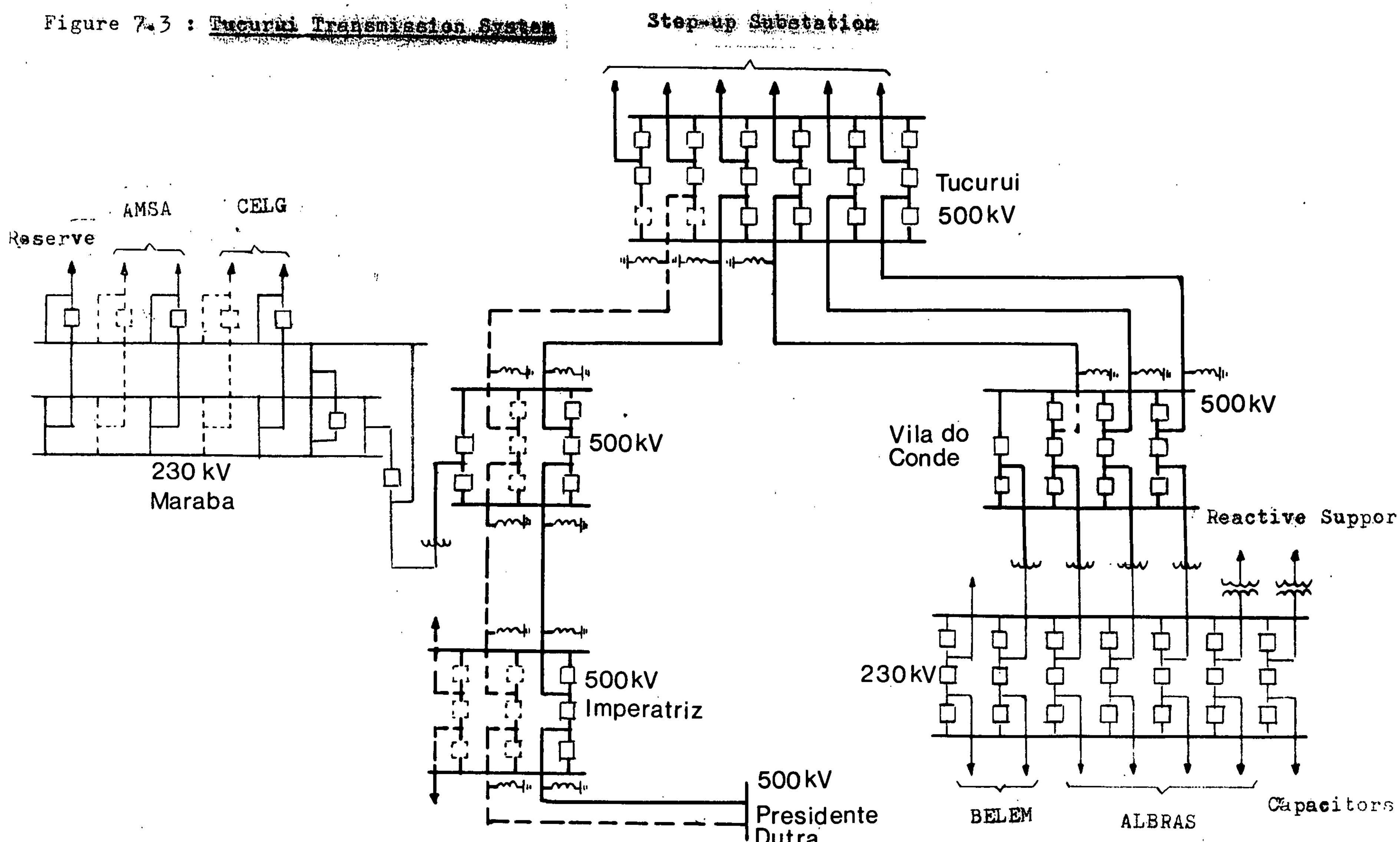
The load area of Imperatriz includes the North East of Brazil, through the CHESF distribution network, and the state of Goiás, through the CELG network. It will be connected to the ELETRONORTE network and to Tucuruī. Imperatriz is well situated on the Belém-Brasīlia Highway, and it is a prosperous town, in an area of great potential development. It is expected to expand with the rational exploitation of its major resource the babassu palm.

The main effect of the Tucuruī scheme on its area of influence is expected to be the expansion of the major towns, and an increase in their industrialisation.

Transmission

A total of 720 km of transmission line will be erected between Belém and Imperatriz, via Tucuruī, and an estimated 10 000 t of construction materials will be required,(See Fig. 7.3).

Figure 7.3 : Tucurui Transmission System



Source : ELETRONORTE "Usina Hidreletrica de Tucurui - Projeto Basico, 1976.

The Tucuruī transmission system will comprise :

i. a transformer sub-station at the Tucuruī power station,

ii. a switching station, on the right bank of the river, downstream of the powerhouse,

iii. the Tucuruī - Vila do Conde 500 kV transmission line,

iv. the Vila do Conde sub-station,

v. the Vila do Conde - Belēm 230 kV transmission line,

vi. the Belēm area sub-stations (Guamā, Utinga, Miramar),

vii. the Tucuruī - Marabā 500 kV transmission line,

viii. the Marabā sub-station,

ix. the Marabā - Imperatriz 500 kV transmission line, and

x. the Imperatriz sub-station(655).

The associated transmission system of UHE Tucuruī will comprise three 500 kV double circuits connecting the step-up sub-station to the switching station, situated on the right bank of the river downstream of the power station. The power will be transmitted over three 500 kV circuits to Vila do Conde, where the voltage will be stepped down, and thence to Belēm through a double circuit 230 kV line. All transmission links will use three-phase alternating currents.

It is expected that considerable difficulty will be experienced in the erection of transmission lines. Much of the terrain is inaccessible and swampy, and there will be difficulty in placing the footings to the towers. The underlying geology is not known, and it will be necessary to conduct surveys prior to erection.

Much of the area is forested, and large tracts of land will have to be cleared prior to siting the towers and lines. As the biomass regenerates itself rapidly it will be necessary to spray the area with herbicdes from helicopters at regular intervals, in order to maintain access. In places, lines will have to span extremely wide rivers, with the consequent need for extra high towers.

Technical Data (See also Appendix 5).

When the first phase of UHE Tucuruī, currently scheduled for 1986, is completed, it will be the largest hydroelectric power station to have been built entirely on Brazilian territory, the second largest (after UHE Itaipu) to be operated by Brazilians. It will consist of an 85 m high earth dam on the right bank, a spillway and power house on the left bank, with step up transformers inside the power house, and embankments on both the left and right banks of

Table VII.i ; Related Transmission System

	Tucuruī V. do Conde	Vila do Conde/ Belēm	Tucuruī Marabā-Imper.
Voltage (kV)	500	230	500
Number of circuits	2	2	2
Length per unit (km)	280	70	383

the river. The total length of the dam and concrete structure will be 4 855 m, and, including the two embankments, it will stretch a total of 11.5 km. The reservoir impounded behind the dam will inundate an area of 2 160 km^2 at N.A. level 72 m, and the resulting lake will be 200 km long and extend upstream to the city of Marabá.

Due to the large number of 500 kV links between the power station and the switching station, it was decided to adopt three-phase transformers with double windings, each connected to one generator. Each generator is connected to the respective transformers which in turn are connected through a circuit breaker to busbars. This system reduces the number of links between the switching station and the power station, making it possible to synchronise and disconnect each generator independently.

The Spillway

The spillway, 575m long, 85 m high and 85 m wide at the base, will be a concrete gravity structure, with its axis at an angle of 14° with respect to the axis of the intakes, so as to reduce the interference effects of the discharge upon the operation of the escape channel. In the body of the spillway will be 40 openings, each 6.5 m x 13 m, capable of draining a total flow of 51,000 m^{3}s^{-1} during the diversion phase. Later, they will be shut off with concrete. Stop-logs on the surface of the spillway will permit the maintenance of the floodgates.

The Powerhouse

The power intake will also be a concrete gravity structure, consisting of 12 blocks, 30.5 m long, and corresponding to each block of the power house. The top of the structure will be 13.7 m wide, at N.A. level 76 m, and the intake will be equipped with 12 steel sluice gates, operated hydraulically. The power house, of the open type, and semi-underground, will be 470 m long. It will be divided into 16 blocks housing the twelve principal generating units of 330 MW each, and two 20 MW auxilliary each. They will operate at a frequency of 60 Hz and a nominal voltage of 13.8 kV. The twelve Francis turbines will have a maximum capacity of 330 MW, and nominal capacity of 316 MW. Under conditions of minimum head, the capacity will be 250 MW.

As the result of a financing agreement between the Brazilian and French Governments (656) all the main electrical equipment for UHE Tucuruī and its associated transmission system will be supplied by French companies. The turbines are to be supplied by Neyrpic-Creusot Loire, and the generators by Alsthom Atlantique, in conjunction with Industrias Elētricas, Brown Boveri and General Electric S.A.. The electrical equipment contracts went to CGEE. Alsthom, Thermatome, Jeumont Schneider, Merlin Gerin and Merlin Gerin/Egic. However, the transformers will be supplied by the Brazilian companies Industrias Elētricas Brown Boveri and ASEA Elētrica S.A.(657-658).

The Site

The scale of operation and isolation of the site requires all facilities to be established at Tucuruī.

For construction of the concrete structures and the filters in the earth dams, a system of stone crushing has been established, with a nominal production capacity of 1650 t/hr. The crushed and graded material is stored separately according to size(659).

As a result of the large quantities of concrete being used, and the heat generated after placement, refrigeration plants are needed to cool the aggregates. Flaked ice, produced by four ice machines, is used for concrete production to keep temperatures down during concrete placement and setting. The three concrete plants are supplied by ten cement silos and six ash silos. The sand required is dredged from deposits on the bed of the rio Tocantins. A compressed air unit has also been set up in order to supply the compressed air needed for transporting agglomerates from the silos to the concrete plant. A water filtering station provides the necessary filtered water(660).

Environment

It must be emphasised that knowledge of the area to be exploited and inundated by Tucuruī lake is almost completely non-existent. An environmental assessment was carried out by ecologist Robert Goodland, at the request of ELETRONORTE, in 1977 (661), but no detailed studies of the area have been made, and it is not known how many indigenous peoples live in the area, what species of flora and fauna are present and in what quantities. The composition of this region rich in life can only be guessed at. There is the certainty of substantial ecological disturbance, but its assessment can only be subjective in the absence of the essential base data usually available from pre-disturbance surveys.

Human ecology

One of the most serious and emotive problems with any hydroelectric scheme which floods a large area is that of the people to be displaced by the water. At Tucuruī this is a particularly sensitive subject in that most of the peoples to lose their homelands are Amerindians, who have no political representation at any level of the Brazilian State organisation. The issue of rights of the Indians is a hotly disputed topic (662). The Parakanan and Gavião Indians in the south of the state of Para are in conflict with ELETRONORTE. The former will have their traditional lands flooded by the Tucuruī reservoir, and the transmission lines will pass through Gavião territory, requiring the felling of many castanha de Parã (Brazil Nut trees) on which the gathering and trading livelihood of the Gavião depends. They are demanding compensation from ELETRONORTE for this loss, but the company has refused, because it believes that it has no responsibility for the Indians, and there is little political pressure for it to do so. As well as the Indians, posseiros* are also in conflict with the company over the possession of land.

It is often very difficult to estimate the number of Amerindians in an area as few are sedentary agriculturalists. Most move their villages from place to place in the forest as a result of their slash-and-burn methods of agriculture. Often it is reported by FUNAI that a hitherto uncontacted tribe has been located, but usually it is a splinter group from a previously known tribe which has attempted to preserve its way of life by penetrating deeper into the forest (663).

It was originally stated by ELETRONORTE that it would draw up a

* Poor peasant squatters from the drought ridden North East of Brazil, who have no tenure over the land which they farm, and who move from place to place as the fertility of the soil decreases.

detailed census and a cadastral survey for the region, around the dam, which has been declared 'Utilidade Publica'. It is, in fact, greater than the area of inundation. All properties would be inventoried for structures, land use, permanent crops, livestock, forest products. Towns and villages would be surveyed for existing public areas, public buildings, shops, markets, dwellings, community resources such as medical, educational and religious facilities, and basic amenities such as water, electricity and sewage disposal. In the case of the Tucuruī, ELETRONORTE was to offer complete and full indemnification for all land and 'improvements', such as dwellings, fences, and plantations, at the prevailing market value. Similarly, the communities to be inundated would be indemnified, and their relocation to new sites would be aided by the Instituto National de Colonização de Reforma Agraria (INCRA) who would supply transport and arrange agricultural credit, assistance and incentives.

When the environmental assessment was made there were no population statistics available. Seventeen settlements were to be affected by the water, see figure 7.4 All these are riverside communities, presumably dependent on fishing for their livelihood. The largest township, Itupiranga, with a population in 1970 of around 5 000 will be only slightly affected by Tucuruī lake. However, the town of Jacunda, which had a population of 2 200 in 1970, will be completely inundated.

Due to lack of statistics, reliance must be placed on Goodland's several estimates for the population to be affected, which ranged from 8 500 to 15 000, excluding the Indian groups living in the forest. ELETRONORTE informed Goodland that it would honour in full all legal commitments to everyone affected, and by late 1977, the

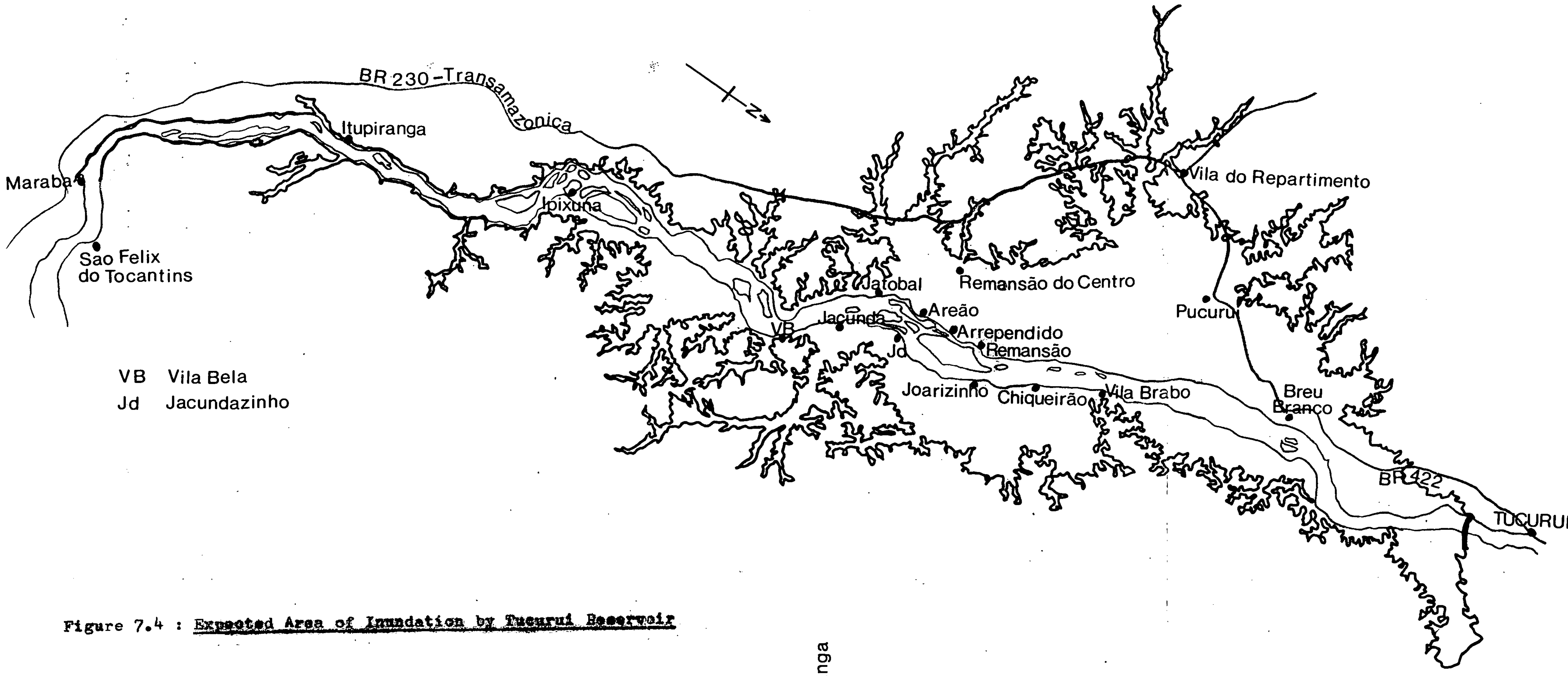
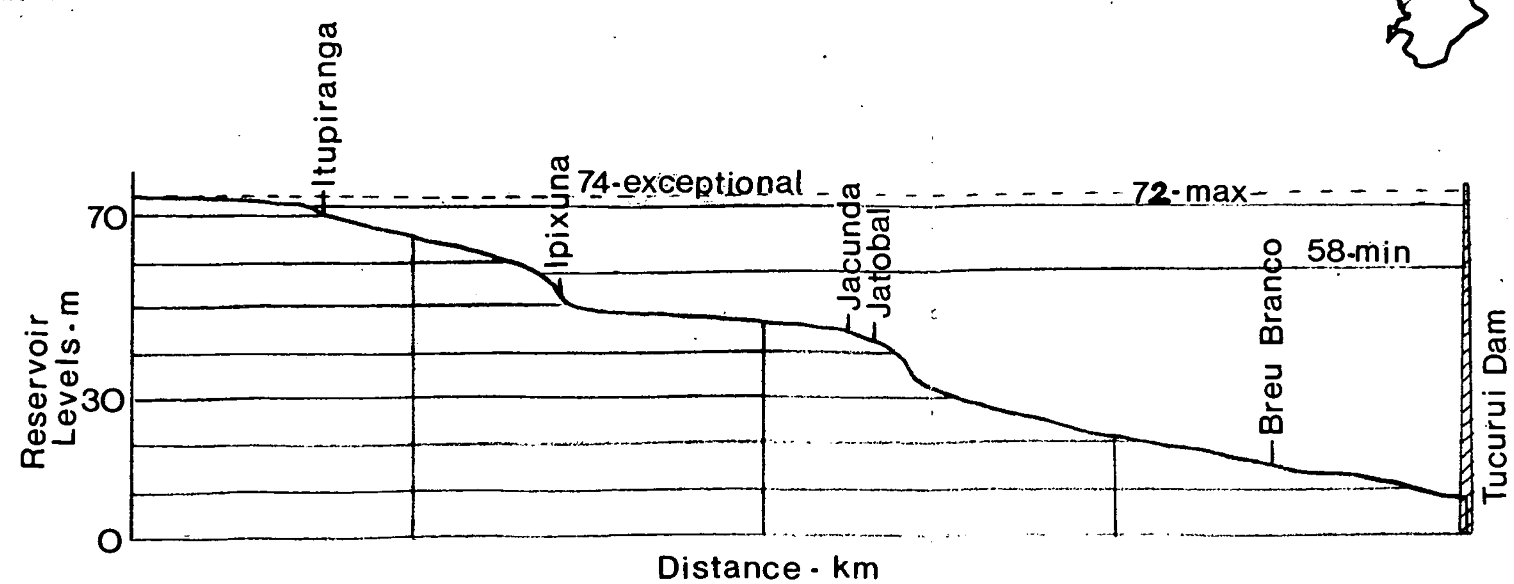


Figure 7.4 : Expected Area of Inundation by Tucurui Reservoir



Source : Goodland R.J.A. "Environmental Assessment : Tucurui Hydroelectric Project, Rio Tocantins", 1977.

survey, inventory and cadastral plans had been formulated and were open to bidders for carrying them out. In the words of Goodland, "this process is progressing in such a humanitarian and conscientious manner that it is not mentioned further".

One wonders why such a remark was made. It is unlikely that its author was unaware of how easily such promises are made and then broken. Perhaps it was a 'placebo' offered to convince ELETRONORTE that he was working on their side. There is no evidence to prove whether these surveys were conducted, but the 'throw away' remark of one of the ELETRONORTE personnel in 1980 that, 'the only people to be moved are 30,000 odd colonial rubber settlers' suggests that little has been done (664).

If the indemnifiers are willing, settlement for loss of property and lands, and inconvenience is relatively simple, especially if there are legal guidelines. However, this is only the case if the claimants have a legal title to the land. Land tenure in Amazonia, as in the rest of Brazil, is extremely complex and its organisation is usually corrupt. Very few people have formal documentary or registered title to the land on which they work and, therefore, they have no legal claim to the land in the eyes of the Federal and State Governments (665). The only people who can afford to purchase land titles are the rich entrepreneurs from the south of Brazil or overseas (666). In the region to be inundated by Tucuruī reservoir very few of the people possess registered and undisputed proprietorship to the land they occupy.

Consequently, ELETRONORTE had decided to accept 'usucapion' - claim to title by uninterupted possession for a defined period. The claimant must prove before a judge that the land has been exploited by him continuously for 40 years (prescricao acquisitiva quarentenaria' or ' praescriptio longisimi temparis') (667) as federal, unowned land, in addition to showing proper humility and having been law abiding. If the land is subsequently found to be owned the period is reduced to 20 years, or even 15 years on invoking the 'in good faith' clause of the 'Código Civil', 1973. If 'usucapion' is accepted, then the 'usucapient' is indemnified as per the proprietor.

Non-settled users of land who live by extraction of products such as nuts, latex, timber and animal hides are 'ineligible for usucapion for twenty years'. The State of Para will therefore offer the land involved for sale at the prevailing rate, or INCRA will cede 100 ha and will auction the balance. Posseiros (see page 281), because they are regarded as squatters are accorded no such rights, and it is proposed to only give them indemnification for any dwelling they may have built.

A significant number of families, up to two-thirds of those affected by Tucuruí reservoir, will have little or no right to indemnification in the eyes of ELETRONORTE. Such treatment could bring great hardship to the already poor posseiros and, possibly, as many as 10 000 will be affected in this way (668). Despite successful relocation of posseiros in the south of Brazil, by ELETROSUL at the Passo Fundo project in 1970, it does not appear that this example, where ELETROSUL provided basic accommodation, wells and septic systems, will be followed(669). Although the posseiros are prepared by the very nature of their existence for movement from one agricultural tract of land to another in a short time period, they will still suffer from the enforced removal from the land without compensation.

Many of the village dwellers along the rio Tocantins depend for their livelihoods on fishing, nearly all of them being riverside dwellers. Goodland suggested, therefore, that their experience be exploited in lake fisheries, and that they should be aided in setting these up, using different fish species and new fishing techniques. On the whole, Amazonia is not suitable for annual subsistance agriculture, the soil being too poor in nutrients to sustain adequate crop yields. Despite the land being covered by lush vegetation, the soil contains very few nutrients. These are all held in the vegetation and lost when it is removed. Loss of vegetation cover also leads to degradation of the soil as it is no longer protected from the penetrating rays of the sun. In addition, the problems posed by pests and weeds are considerable.

The area to be inundated is rife with social unrest (see page 274), with many land disputes being resolved through violence. In the five year period 1971 to 1976, half of such reported land disputes produced victims of violence, and of these more than half led to deaths. A greater number of people are killed than are wounded, and many more have their property destroyed (670). Poverty is widespread and endemic, as is reflected by the rising infant mortality. Crop yields are low, food prices are high and rising. All these problems are exacerbated by waves of new immigrants from the drought stricken northeast of the country. The whole situation is critically inflammable but is, as yet, played down by the media. ELETRONORTE has requested outside researchers not to delve into such sensitive topics as 'expelled officials, muzzled priests, imprisoned politicians, subversion, murdered soldiers' (671), although it is not directly implicated.

It is within the power of ELETRONORTE to improve the local social conditions and, in fact, much has been done in the old town of Tucuruī(672),(see page 266), but, equally, it is within the company's power to reduce the quality of life of many people by insensitive and unfair indemnification of real losses incurred as a result of the Tucuruī scheme.

Amerindians

The plight of the surviving Amerindians of the Amazon Forest is a better known, and an internationally sensitive, problem. Knowledge of their condition is well known to anthropologists, who have been more assiduous in studying primitive tribal societies, than in studying the displaced poor created by the impact of the modern industrial society. The media, too, is undoubtedly more interested in the fate of tribal societies; it makes for better headlines. Despite this, the plight of the Amerindian is relatively worse. He is less used to fighting for his lands, he is certainly less versed in the ways of the large company and in adjusting to the modern world. The posseiro has learned to fight and those who survive move on. Often very few of the Amerindians survive when faced by the same pressures.

How many Amerindians will be affected by the Tucuruī scheme is not easy to estimate. The nomadic nature of many of these people, and their mistrust of the white man or non-forest dweller, coupled with the cover up operations of FUNAI and ELETRONORTE, make it difficult to assess the situation with any certainty. According to Goodland the three indigenous reserves which will by affected by the Tucuruī project are the Parakanan, the Pucuruī and the Mae Maria. The first two will be inundated by the reservoir, and the transmission lines to Imperatriz will cut through the Mae Maria reserve, along with the Carajas iron railroad (if it is built) and the Tucuruī - Belēm highway (673).

The Amerindians in this area have already suffered the pressures of advancing pioneer fronts. From the 1950s onwards there has been a substantial influx of 'civilizados', and the opening of the Transamazonica from Marabã to Itaituba on the rio Tapajos. In order to mitigate the adverse consequences of the Tucuruī project on the Amerindians in the region, FUNAI developed a plan of action, which was presented to ELETRONORTE in 1977. It included an aerial survey, to be followed by a land expedition designed to identify all tribal groups of Indians present, to estimate their numbers, and the size and home range of each tribe.

A special FUNAI expedition was proposed in order to make an inventory of the Parakanan reserve, and to determine Brazil nut tree stands, fertile plots of land, holy sites and burial grounds. As part of the plan of action the Amerindians would be encouraged to take advantage of free medical services, including appropriate prophylactic vaccinations. No proposals were included however, for educational or agricultural assistence to be offered. The fifth part of the plan was the relocation of the FUNAI post from the Pucuruī reserve.

Despite the great cost of building the Trans-Amazonian highway, the Tucuruī reservoir will flood a 40 km section between Jatobal and Repartimento, in addition to the 65 km of the BR-422 connecting Vila do Repartimento and Tucurui. The stretch of the Transamazonica to be inundated is at present the eastern boundary of the Parakanan reserve, and the shortest and cheapest re-routing of this section would penetrate deeply into the reserve. It is considered, by FUNAI, that this would be even more harmful to the survival of the Indians than the projected inundation.

Even with the greatest of goodwill, indemnification of the Indians for their losses will be a difficult subject to deal with satisfactorily. In 1976, FUNAI submitted a calculation to ELETRONORTE of the indemnity required for the deforestation of a 19 km by 10 m strip in the Mae Maria reserve. However, it was then discovered that due to a bizarre legal anomaly there is an impediment to indemnification, with the result that ELETRONORTE asserted that there was no necessity whatsoever for it to pay any indemnity to the Indians for loss of use of the trees(674). In the end, the company suggested that indemnification should depend on the actual value of the destroyed trees, rather than on the ten year loss of future profits, as suggested by FUNAI, and that the payment was not to be made in advance. The impasse was not broken, and a Presidential decree was issued at the request of ELETRONORTE, authorising the company access to lands 'in the interests of national development'. There is now no need whatsoever for any indemnity to be paid.

What the Amerindians will suffer and lose as a result of the Tucuruī project can only be guessed at and accurate and honest reports after the event will be difficult to obtain. However, it is fair to assume that ELETRONORTE will pay out very little for what the Indians will lose.

Flora and Fauna

The Amazon region is the richest in the world in terms of the variety of its flora and fauna. It is believed to contain many species as yet unknown to man, and, with the inundation caused by the Tucuruī reservoir, some may be irretrievably lost. For any substantial development of the Amazon basin such a loss is inevitable and incalculable. A few well known mammals will become further endangered, as will plants and insects and other forms of wild life in the area. But without detailed surveys little can be said of the losses which will occur. However, it is certain that habitats and species will be lost, and ecosystems disrupted.

Judging from ELETRONORTE's response to other environmental aspects of the project it is extremely unlikely that there will be any animal rescue as was arranged at the other Amazonian project of Lake Brokopondo in Surinam (675).

Social Problems

The very isolated nature of the Tucuruī scheme leads to a number of specific problems. The lives of the workforce are very much run by ELETRONORTE, which supplies everything, including the meals, and this has resulted in serious unrest.

On Easter Friday, 4th April 1980, when tensions had been running high for some time, there was a fatal clash between the peons* working on the construction site, and the security agents of the construction company, Camargo Corrêia. The peons had made a "Judas

*Peon - manual labourer recruited from the North East and Goias.

doll", as was traditional, to be flailed on Easter Sunday, but they had dressed it in the uniform of the site internal security service. According to one report(676), more than 2 000 workers had been participating in this "jest", and they had attempted to process with the "Judas", to which they had attached posters criticising Camargo Corrêia, to exhibit it in the principal square of the Vila Temporaria, in which reside about 12 000 of the workers and their families.

Some of the security agents, on learning of the procession, attempted to interrupt it and to prevent the displaying of the "Judas" in the security agent uniform. The security agents took it upon themselves to arrest four of the leading demonstrators. The other demonstrators reacted to this, and in retaliation the guards discharged their revolvers in the air, but shortly followed by then shooting into the crowd, causing great confusion.

A group of peons then resorted to vandalism, which rapidly escalated, with the setting on fire of two kombi vans, the raiding of a supermarket, the robbing of a restaurant and some of the hostels. The fire station was prevented from sending fire fighters to put out the fires which had been started. The situation became chaotic, "shots and cries were heard, and there was running in all directions" according to one eye witness(677). Another newspaper reported that eight peons were arrested and taken to the Delegacia (Police Station), and that by 2 a.m. 2 000 peons had overcome the security sentry box and the Camargo Corrêia security centre, setting fire to them both.

Shots were fired at the demonstrators, but, by virtue of numbers, they were able to overpower and disarm the guards. It was at this stage that it is believed that some deaths occurred. One report claimed there were six, one of which was a child(678). By 3 a.m., the Policia Militar (Military Police) had been called in, and they soon gained control of the situation, with the peons agreeing to return to their homes on condition that the prisoners who had been arrested in connection with the "Judas" were released. The Delegado de Policia de Tucuruī (Police Commissioner) agreed to this, and the first part of the rebellion was contained.

However, the continued presence of 60 members of the Policia Militar caused great tension throughout the districts of Tucuruī and further arrests were made during the morning. The peons went to work as usual on the Saturday morning, but the situation became more inflamed when further police reinforcements arrived from Belēm and Marabā, together with twelve extra Policia Militar flown in from Belēm in a specially chartered aeroplane. A new revolt started in the refectories, with the workers complaining about the food, and the compulsory deductions made from their salaries. These deductions are to cover the cost of food and bedding, and some workers often find it difficult to understand exactly what the ELETRONORTE deductions are, because, in some cases, it is claimed they reach as much as 70% of the total salary.

Most of the permanent workers are obliged to remain at the site until the completion of their contracts. They have insufficient resources to make visits to their home towns, and have no control over the food with which they are supplied. At unskilled levels 1 and 2, they are given rice, eggs and beans in the refectories; whereas workers at level 3 and above receive fish(679). At the executive level the food is excellent with a wide choice of dishes in waiter service restaurants,(a personal experience). According to one employee:"the work on the site is done under tension, the peon is rebelling because his money is deducted, because he eats badly and because he is treated badly by the security men". This was given as the explanation for the action of the peons with the "Judas". They wished to attack Camargo Corrêia and, especially, the security agents who, despite only earning the same as peons at levels 1 and 2, are armed and dressed in uniforms and treat the workers with violence and discrimination. The working conditions are the same in almost all the large projects in Amazonia. In 1973, peons at the Jari project made a protest about the food during a visit of President Medici to the company. In 1978, there was a mutiny amongst the peons at the mineral company, Rio do Norte, which is exploiting the bauxite at Trombetas. However, the riot at Tucuruī is probably the more serious because of the large numbers of people involved and the heavy investment commitments made in this enormous project(680).

In the end, the rebellion was contained by large numbers of police, because, according to the Delegado de Policia de Tucuruī, it had been feared that the rebels would gain possession of the store of dynamite, which Camargo Corrêia held for excavation of the river bed(681).

The truth behind the whole episode is not completely clear. The headlines in the newspaper "Estado do Minas" were : "Dez mortos na rebelião en Tucuruī" ("Ten dead in the Tucuruī rebellion"), although the report below later stated that on the site, the story was four peons and two security men were killed during the skirmishes and a child died, probably from a random shot or by crushing in the general pandemonium following the first shots(682). Whereas in the "Folho de Sao Paulo" newspaper, a death toll of six was reported, one of whom was a child who died during the sacking of the supermarket(683).

Camargo Corrêia headquarters in Belém initially claimed ignorance of the situation although a chartered aeroplane with Military Police reinforcements had been dispatched, under their auspices, from Belém to Tucuruī. However, by Saturday afternoon there was a complete embargo by Camargo Corrêia on the publication of information. All the journalists and press officers were called to the Director of Works, where they were told that : "There are no dead, only four injured,repeat, only four injured, three slightly and one more seriously"*. However, it was still reported in the popular press that deaths had occurred. A journalist, from the "Folha de Sao Paulo", present at the rebellion, estimated the numbers at five adults and one child, though he reported a Camargo Corrêia telephonist as putting the number up to eight, and an ELETRONORTE telex operator reporting no more than three. The report finished with the hope that an official notice from the Secretaria de Seguranca, expected later that day, would reveal the actual numbers of dead and injured(684)*.

The consequences of this level of unrest could be extremely serious. In such an isolated location large numbers of rebellious

* These two reports were displayed on the ELETROBRAS head office notice board by the Departamento de Assessoria for general information. But, subsequent to copying down the information, no more notices appeared, and access was refused to the press cuttings file, so there was no available information on the outcome of this riot at Tucuruī.

workers would be difficult to contain, and strikes would slow down considerably the construction work schedule, and jeopardise the several thousand million dollar investment. It is an extremely harsh environment in which to work, hot and humid with almost prison conditions, and, therefore, poor food and poor management decisions are keenly felt. Many of the peons are from the drought ridden north-east of Brazil, and are grateful to escape from starvation conditions, but if the operating companies try to capitalize on this, the project may not be completed successfully.

Forest Problems

The lake which will be formed behind the Tucurui dam will be some 200 km long, and will inundate an area of 2 160 km^2(685). The entire area to be flooded is almost totally primaeval tropical rain forest, and there is considerable controversy over the best method of dealing with the available wood, as the wider implications are not understood. At the engineering level it is treated lightly; "but Tucuruī is in an area which is flooded annually anyway"(686),"and only some areas have large trees of valuable hardwoods"(687).

To date only one survey has been made of the area to be inundated by the Tucurui lake. This was the environmental reconnaissance made by Robert Goodland in order to identify and assess the potential impact of such inundation. The survey was carried out in 1977, when little data was available or made available, and many of its conclusions are based on Goodland's own extensive experience of tropical rain forest ecology, rather than on verified facts.

Despite the recommendations made in the report, a further survey will not be made until one year prior to inundation. In an agreement reached between INPA and CNPq, INPA will make a comprehensive study of the area over a period of five years, commencing one year before closure of the dam(688).

It is very difficult to assess the effects of inundation because this will be the largest expanse of tropical moist forest in the world to be flooded by a reservoir in the world. Only one other of the world's large reservoirs is located in a relatively undisturbed tropical forest region, Lake Brokopondo in Suriname,(area=1 500 km^2). A number of detrimental and unpleasant effects were observed after the closure of the Brokopondo dam, with noxious gases being generated and a eutrophied lake resulting(689). In Brazil itself, there has been no experience of reservoirs under moist tropical conditions. Most of the others are situated in cerrado*, savannah or semi-desert regions, and a few are in temperate areas of agriculture or disturbed forest. (Itaipu is one of these).

There are two small reservoirs in the Brazilian Amazon. Coaracy Nunes was created in 1975, and the small area, 23 m^2, flooded contained a mixture of savannah and some seasonal and riparian forest. The floding of such a small area has caused few problems. The area of 86 km^2 of reservoir behind the 20 MW Curua-Una hydroelectric power station was not cleared before inundation; and, even during the filling process, decomposition gases were noticed by people 60 km distant, who complained of a sulphurous smell (690).

*Cerrado - vegetation corresponding largely to the Central Brazilian Shield.

So, furnished only with the experience from these two small schemes and the example of Surinam's Lake Brokopondo, ELETRONORTE and the Brazilian government have had to try to decide on the best policy for treating the area of forest to be inundated by Tucurui lake. Although the area of inundation of Lake Brokopondo contains features similar to those of Tucurui, there is, in the opinion of Goodland, one significant difference, Lake Brokopondo has almost never spilled water and, in fact, electricity generation has been curtailed in order to maintain reservoir levels. The streamflow through the lake is slow, and hence the water retention time in the lake is long.These conditions will not be found at Tucuruí. The average flow of the rio Tocantins is 9 000 m^3s^{-1}, and when twelve of the UHE Tucurui turbines are in operation, the total discharge through them will be 6 900 m^3s^{-1} (see appendix 5). Over an average year there will be 22% of excess water to be spilled resulting in fast circulation and short retention time for the water in the reservoir.

As the rainfall in much of the Tocantins basin is seasonal,Tucurui reservoir will be subject to a dry season, during which the drawdown on the reservoir will be up to 14 m, in order to maintain the power output. This large drawdown is much greater than that of Lake Brokopondo, which at most drops 3 m below nominal level in a year. Such a large drawdown in Tucurui, coupled with the fast river flows in the wet season, will facilitate better aeration of the water and thus lead to different mechanisms of decomposition of the forest wood should it be flooded(691).

Before it was dammed, the Suriname river was oligotrophic and slightly acidic (pH 6.5). After closure this dropped to pH 5.3, as a result of decomposition of the organic matter from the forest.

Hydrogen sulphide was produced and caused an objectionable nuisance to people many kilometres down-wind. This took some years to clear and, eventually the pH rose to a level of pH 7.3 eleven years after closure. Over the intervening years the lake was dead and odorous. It had a very low oxygen content and, in fact, the water was not reoxygenated below the dam, thus causing depletion of the fisheries in the Suriname River estuary. There was considerable trouble with the proliferation of the Water Hyacinth (Eichhornia crassipes), which, by the third year after closure, covered 40% of the reservoir surface. This was dealt with by chemical spraying, resulting in the decomposition of poisoned water weeds, which had sunk to the reservoir bottom.

Reoxygenation of the river below the dam has now taken place and fish have returned, whether or not to previous levels cannot be guaged, as no fish studies were made prior to damming the river. Nor were the relative contributions to deoxygenation by forest decomposition, floating waterweed mats(as a physical barrier to oxygenation), decomposition of killed waterweed, and little turbulence assessed. Although Lake Brokopondo is the most similar reservoir to the Tucurui lake to be formed, there is very little factual information available about the former on which to base projections on what will happen to the latter if 2 600 km^2 of forest are inundated.

Where timber has been left standing in the water, there are many major effects which have been observed(692). The major practical contention is whether or not it is economically worthwhile to remove the vegetation from reservoirs prior to flooding. Much of this argument depends upon the proposed use of the reservoir(693). At

Tucuruī, the commonest concern is that of the decomposition of the vegetation which will occur if such a large area is left uncleared prior to flooding, and whether the decomposition will be aerobic or anaerobic.

No oxygen concentrations in the water in the project area had been determined at the time of the environmental assessment, but they are related to the retention time of the water in the reservoir, the depth, the temperature and the speed of circulation. At Tucurui these factors favour oxygenation of the water. ELETRONORTE calaculated the mean water retention time in the reservoir to be two months. It also calculated the average depth of the reservoir to be 20 m or less, which is, approximately, the greatest depth to which oxygen penetrates(694). When the reservoir is at the normal maximum level, 50% of it wil be less than 17 m deep, and at the low level the depth of 50% of the reservoir will be less than 7 m(695). Therefore, most of the lake will be shallow enough to be oxygenated from the surface by diffusion, turbulence and photosynthesis.

Goodland considered that much of the forest will decompose rapidly under aerobic conditions. The decomposition will be at its most rapid during the months of fill, slowing down as the maximum operating level is reached and then accelerating again during the drawdown period. During the aerobic decomposition, the acidity of the water will increase due to carbon dioxide dissolution and by formation of acids of the humic series(696). In addition, most of the Amazonian trees have highly acidic wood (pH 2.6), and Goodland expects that most of the softer parts of the trees will have decomposed by the third drawdown period, that is, within three years. The fully submerged trees in deep water will take much longer to decompose.

Some of the vegetation will change as a result of frictional ablation of the softer parts due to scouring action of suspended sand particles, but the extent of such ablation cannot be estimated as there is no relevant data available. Mechanical damage will also occur due to falling trees hitting others which are still standing, and floating trees which will crash into standing trees downstream because of the high river flows which occur.

Goodland assumes that there will be little anaerobic decomposition within Tucurui lake because of the rapid water circulation and the shallow depth. The deepest parts of the reservoir will be immediately behind the dam and in the former river channel, but the bottom of the penstocks are set low in the dam, and it is unlikely that there will be much stagnent water below them.

Stop-logs protect the diversion galleries and at high water these could be opened briefly and periodically to improve aeration by turbulance. Thus, the most likely place for anaerobic decomposition will be in the deep water behind the eastern section of the dam and in the channel behind it. The main problems caused by this will be the production of the poisonous and offensively malodorous gas, hydrogen sulphide, and the precipitation out of insoluble iron and manganese sulphides.(Iron and manganese are abundant in the latosols of the area to be flooded).

Although Goodland considers that anaerobic decomposition in Tucurui lake will be restricted, both in area and seasonal duration, he recommended that the risk zones should be cleared of major vegetation.

Eutrophication is unlikely to be a major problem as the water flowing into the reservoir is oligotrophic(697) and carries virtually no accumulated fertilizer. However, particularly in the upper area of the drainage basin, the rapid development and immigration to the area will intensify agriculture(and fertilizer use), extensive deforestation, burning and erosion. All such activities would augment the inorganic nutrient loading in the rivers. Although the forest contains only 5% of inorganic nutrients, the bulk of them occurs in the leaves, fine twigs and bark - all those parts of trees which are susceptible to anaerobic decomposition when in water.Although unmeasured, the biomass of the forest is extremely large and the release of these inorganic nutrients into the water could be significantly high.

According to Goodland, the physical effects of flooding the Tucurui forest need not be too serious. An advantage of leaving the trees standing would be the erosion protection offered to the lake bed. However, standing trees prevent easy navigation, an earlier aim of the scheme, and fishing. Mechanical interference with the dam and auxilliary structures could occur due to sunken rolling logs and floating timber. Trees left standing in the reservoir will break off or fall down from the start of inundation and will continue to do so for decades. It is possible that much of this floating timber could be exploited commercially at a profit, and the unmarketable wood be salvaged for domestic fuel or charcoal production and export(698).

Accurate estimates of the quantity and variety of the timber to be inundated have still to be made, but a large quantity of floating timber can be expected, and it will be necessary to incorporate some kind of protection system to avoid damage to the reservoir structures such as special spillways for voiding logs, intake grilles to withstand the timber, equipped with grille cleaners or substantial trash racks. Similarly, if navigation and fishing are to be important uses of the lake, some selective reservoir site clearance must be effected prior to inundation in order to provide for net fishing and navigation channels.

The most obvious effect which will be felt if the forest is not cleared is the major financial loss due to drowning of commercially valuable timber. In 1977, Brazil was a net importer of wood and wood products, hence the flooding of some 2 000 km^2 of high grade timber would represent a considerable waste of an indigenous resource. However, it is not easy to set up logging operations prior to flooding in this extensive, isolated region. At the time of the environmental assessment, in 1977, it was planned that the bulk of the forest would be abandoned unused. Under the presidential "Utilidade Publica" decree the land to be inundated does not become the property of ELETRONORTE until the flooding starts; and the company, therefore, disclaimed responsibility at the pre-inundation phase. It was claimed by ELETRONORTE that forest utilization was not "economic" because the land belonged to others, transport costs exceeded benefits, similar timber was more accessible closer to the markets, and so on.

Goodland recommended a specific reservoir clearance plan to be designed and executed before closure of the dam. He suggested that a detailed study be made to avoid adverse consequences. However, due to ELETRONORTE'S refusal to delay the construction schedule there has been insufficient time for effective study.

Despite the strong recommendations made by Goodland, in 1977, there was, by 1980, no indication that any detailed forest inventory had been made nor a clearance plan designed. More recently, however, there have been many of signs that the Federal Government has suddenly become aware of the potential revenue from the forest, and hence moves have been made to start exploitation of the wood. However, it has become obvious that the clearance will be undertaken more or less at random and according to the whim of the firms awarded clearance contracts, rather than according to a specific plan which has considered navigation channels, erosion, water-weed control and areas of anaerobic decomposition, and the needs of the fish.

The Brazilian authorities have been largely undecided about the fate of the wood in the Tucuruí reservoir area. They appear to have been overwhelmed by the enormity of the problem and the large number of unknown factors. Two years after Goodland's environmental assessment, the Instituto Brasileiro do Desenvolvimento Florestal (IBDF) and ELETRONORTE signed an agreement under which IBDF would supervise the working of the 2 160 km^2 of the forest to be flooded. According to the surveys then made, there were approximately 13.5 x 10^6 m^3 of first class hardwoods, including mahogany, and 20 x 10^6 m^3 of potentially exploitable second grade wood for use as charcoal or firewood(699).

IBDF required that any companies, bidding for contracts for the cutting and processing of the lumber, must have a majority of Brazilian capital in order to ensure that Brazilian interests control the lumber operations. At one time, it had been feared that the Federal Government would open the area to foreign enterprises, and that, once the operations in the Tucuruí area were complete, they would seize the opportunity to move to other regions of the Amazon, creating additional areas of devastation (700).

In October 1979, it was reported that a competition for the rights to extract the timber would be convened by notice to be published at the end of the month. Multi-national firms were to be allowed to bid so long as they were part of a consortium led by a Brazilian enterprise. The only financial requirements called for by ELETRONORTE were a minimum capital of Cr\$ 20 x 10^6 (\$ US 600 x 10^3 at 1979 rates) and a bond of security worth 20% of the value of the bid entered by the firm. In this way ELETRONORTE was exhibiting caution by demanding a banking surity and guaranteeing the financial capacity of the interested firms.

Despite the earlier report, in October 1979, of ELETRONORTE's intention to award contracts for the exploitation of the timber, the President of IBDF, Carlos Neves Galluf, was obliged, in February 1980, to place the blame for the short time remaining for extraction of the timber on the delay of ELETRONORTE'S decision with respect to the bidding.He denied a Federal Government statement that only 40% of the wood at Tucuruī would be utilized as a direct result of the short time remaining for deforestation prior to inundation. He added that, despite this short time, the reason that only 40% of the wood would be commercially developed was that in accordance with a survey completed by SUDAM it represented the percentage of exploitable first class timber. The rest would be used as charcoal(701). Galluf commented on the rigid terms of the competition for the right to extract the timber. By this time there was a demand for a minimum capital of Cr\$ 500 x 10^6 from the firms. This high figure was to ensure that the high investment costs, in terms of equipment needed for deforestation, could be met. He added that there was no intention to exclude the exporters from the north of Brazil from the bidding, as had been claimed by Paulo Correia, the President of the Associação de Exportadores de Madeira do Para and Amapá(702).

By 1980, the township of Tucuruī itself had developed interest and concern over the utilization of the timber and a number of articles appeared in the local newspaper, "A Folha de Tucuruī" at that time. On the front page appeared a pointed attack on the bureaucratic absurdities which were proliferating. The Paraense timber firms, and those from Amazonia in general, were finding it impossible to compete with overseas interests for the extraction of the timber at Tucuruī, because of the prohibitive capital demands required by IBDF, and the State Governor of Pará, Alacid Nines, had pledged himself to the cause of the local companies and was attempting to arrange a meeting between IBDF and the Ministers of Planning and Agriculture, with the intention of setting a lower capital requirement(703).

Within ELETRONORTE itself there was no obvious great concern. The whole subject was dismissed in a couple of sentences: "There is an agreement with IBDF about the inundation question. Certain areas will be deforested but, from the experience gained from the Jari project, only some areas contain valuable wood. This will be cut for use, but, anyway, Tucuruī is in an area which is flooded annually"(704). This is neither an informed nor interested view, and the last remark clearly demonstrates ignorance or dishonesty. Although the Tocantins floods annually, the waters do not rise sufficiently to flood the entire 2 160 km^2 to be inundated by the Tucuruī reservoir. The speaker also commented that "the vegetation growth is rapid, if deforestation takes place now,(1980), by the time of the dam closure in 1983 the trees will have grown again. At Jari, within two years of clearing, the biomass was 60 - 70% of the original"(705). This neglects the fact that the biomass cover will be of a different nature, and will not include large trees (see page 233).

The overall attitude of ELETRONORTE to the use of the wood may be summarised by an observation made during a visit to the dam site - the wall covering in the offices at Tucuruī was made of formica with a wood grain pattern!

A contract, awarded by ELETRONORTE to INPA for a "half billion dollars" was principally for studies of health and general environmental effects(706). No allowance has been set aside for forestry research. Estimates of the quantity and type of wood in the forest are incomplete, but even if only three species of hardwood are considered, the potential revenue from their extraction is of the order of $US 1 to 4 x 10^9(707).

Estimates, by one of the INPA forestry experts, put the volume of lumber at 115 m^3 per hectare, which gives a total volume of nearly 24 x10^6 m^3. Even considered only as firewood, this represents an energy content of approximately 300 x 10^6 GJ (708).

The figures for the resources potential of the forest are not always in agreement(709)theinventory survey put the incidence of castanha de Para(Brazil Nut) at 40 m^3ha^{-1}, but when an official from INPA flew over the proposed area of inundation with a taxonomist no trees of this variety were observed(710). However, in the opinion of the INPA official, the problems being experienced at Tucuruī should not occur with the developments of the rio Xingo, because there will be more time available for planning and execution of timber extraction and environmental protection. In the case of Tucuruī, ELETRONORTE will not delay the construction schedule for environmental cosiderations, and this, coupled with the lack of a basic infrastructure, difficulty of access to the area, and lack of necessary deforestation equipment and trained personnel, means that economic removal of the timber in so short a time is difficult(711).

The problem of utilisation of the timber has been considered at Federal Government level and, in 1980, a law was under preparation in order to define forest policy(712), but it was too late to resolve the problem at Tucuruī.

Set-backs were also experienced in the awarding of contracts to undertake the necessary work. In May 1980, the process of awarding them was cancelled as a result of the inadequate information contained in the four proposals presented by bidders. It was revealed by Roberto Amaral, Commercial Director of IBDF and head of the commission for awarding the contracts, that the proposals received were more akin to letters of intent and did not satisfy the demands set down by the IBDF. In addition, various undisclosed consortia had compromised the requirements laid down, secure in the knowledge that more time would be given for submission of proposals. As a result IBDF rejected all the proposals and reopened the bidding for contracts, with the intention of awarding them in June that year(713).

Although the question of the timber at Tucuruī has not been resolved, no allowance has been made by ELETRONORTE for the increased time required for deforestation and the construction and lakefill schedules will not be adjusted for this reason(714). Also, having eventually encouraged the interest of a number of consortia in the extraction of the timber at Tucurui, the original area for extraction activities has since been extended to a much greater area than that to be inundated by the resevoir.

In the beginning, the pioneering nature of the contract work was identified as the principal factor in the poor number of proposals presented by interested parties, and this had already forced an extension in the time allowed for the submission of proposals. Therefore, when the time for the competition was extended, the IBDF did not expect new candidates to appear. Although bids for the contracts had been slow there had not been complete disinterest; on the contrary fourteen firms had met the terms of the competition. The president of the Associação Brasileira dos Produtores de Madeira, Nodario Azeredo, was not surprised by IBDF's decision to reopen the competition for contracts. He was quoted as having already forseen it, and, according to him, the conditions required by IBDF would have to be altered so that the local wood industries would be able to compete. However, for this to happen the security of capital demanded would have to be reduced from the Cr\$ 500×10^6 back to a more realistic Cr\$ 50×10^6. Azeredo further stated that the "IBDF had wanted to resolve the problem in an authoritarian manner"(715).

Initially, the region to be inundated by the Tucurui reservoir was divided into seven plots, to be handed over for private development, and a further three experimental areas reserved for the IBDF, which had not defined how it would use them. The wood which the IBDF could extract from these areas could be exported, in order to open up the market, but principally the areas would be used to study the diverse species of trees in the region. Although IBDF had not proposed to give one sole bidder a monopoly on the extraction of timber, all of the bidders expressed the opinion that they had no intention of sharing the contract between seven(716).

The whole question of the extraction of the timber extends far beyond Tucurui. As it is intended that much more of the Amazonas Basin will be developed for hydroelectric power production, it is not a question which will be easily resolved. 'It is a question of negotiations for twenty years' stated the director of IBDF. In that time the total area to be inundated will be 15 000 km^2, which will yield approximately 100 x 10^6 m^3 of extractable wood and generating \$US 30 x 10^9 over 20 years. According to calculations by IBDF there will be an annual revenue of \$US 1.5 x 10^9 towards the country's balance of payments(717). In order to guarantee a good flow of exports, the firms involved would have to have a high level of operational management, infrastructure and technology in the field of extraction. Due to the inexperience of national entrepreneurs, foreign expertise and capital will, inevitably, be present in the Tucuruí project, although, there was no information available on the sources of external capital which the consortia bidding for the contracts have access.

As of 1982, this was the situation, with almost everyone concerned having lost sight of the reasons for extracting the wood. Inevitably, whatever happens, there will be a great ecological disaster. Whether it is deforested or not prior to inundation, the area will not be adequately studied, and many species of tree, plant and animal will be lost and little new knowledge will result. At worst, it is possible that there will be an extremely large, unpleasant and dead environment covering 2 160 km^2. For the time being, it appears unlikely that there will be any effective environmental management of this area, although it was strongly recommended by Goodland.

In the last few months of 1982 there were some new developments in the saga of deforestation at Tucuruī. In order to help fund the deforestation programme which is now under way, a Government run pension fund has been misappropriated and there are rumours of a great scandal. In addition, it is also rumoured a defoliant has been used to remove the leaves from the trees. The same defoliant was used in Vietnam with devastating effects on both people and environment, and it is frightening to think of the scale of the damage which may have been experienced at Tucuruī(718). Unfortunately, the scandal involved in these activities is such that there is a complete news blackout, and it is not possible to discover the extent of what is occurring.

CHAPTER 8

Summary and Conclusions

Summary

When considering the development of hydroelectric power in Brazil, it must be remembered that although Brazil is regarded by many as a Third World country this is not really the case. Any development which takes place in Brazil does so not only against a background of urban poverty and rural decline but also against another backdrop of indigenous scientific and technological expertise and personal wealth. It is a country of extreme differences, reflected in its terrain, climate and peoples - from humid tropical rainforest and Amerindians in the North, drought ridden plains populated by peoples of African descent in the North East, to the hilly more temperate and fertile regions colonised by Europeans in the South and South East.

Brazil possesses substantial mineral deposits, including some of the world's largest reserves of bauxite in the Amazon region. However, despite considerable prospecting, known oil reserves are not substantial and this fact colours the whole energy picture in Brazil. This paucity of oil reserves, plus the existence of indigenous uranium and abundant hydraulic reserves has meant that, like the past and present, future energy policies in Brazil will be determined principally by the availability of hydroelectric power.

In Brazil today, the stated aim of the electrical power industry is that it will meet the electricity needs of the country whilst ensuring that the expansion is compatible with market requirements. At the same time, the power industry is to contribute to the development of Brazil by participating in the rationalization of energy use - by promoting the use of renewable and/or other national energy sources, by encouraging the appropriate use of electricity and by participating in multiple development programmes of energy resources. These objectives have developed over the years and reflect the consistent path which the electrical power industry in Brazil has followed since its inception.

Commercial electrical energy has been available in Brazil since 1879, when regular illumination was provided at the central railway station in the city of Rio de Janeiro. At the end of the nineteenth century the country was introducing the same electrical services as were available in Europe and North America.

Except for those power stations under the patronage of the Emperor, power stations were constructed in order to supply electrical energy for industrial purposes - setting the pattern of the Brazilian electrical power industry right from the beginning. Thus the power industry in Brazil is a major industry which has developed hand-in-hand with the manufacturing industries.

The first Brazilian hydroelectric power station was built by an autoproducer, in 1883, in order to extract gravel. At the time, the 2 km long transmission line was the longest in the world; indicative of the pioneering nature of the Brazilian electrical power industry which has maintained its impetus for over 100 years.

The industrial autoproducers constructed their own distribution networks and supplied electricity to the local populations. At the same time some Brazilian cities installed public supply systems. By the end of 1892 electricity was widely exploited by Brazilian industry, with small industries being established close to falls of water. The move from an agricultural base to a substantial indigenous manufacturing industry was led by hydropower.

Most of the early initiatives in the Brazilian power industry were in the use of hydraulic energy and, by 1909, the commercial potential of this energy source had attracted overseas companies and foreign capital. The resulting foreign domination was to be maintained until the late 1960s. By 1962, two companies, Rio Light and Sao Paulo Light, both subsidiaries of the Canadian company Brazilian Traction, Light and Power Company Limited (known as 'The Light'), were responsible for 46.9% of energy sales whilst supplying only 15.2% of the population.

The first major energy supply crisis occurred in 1924 as a result of a severe drought in the industrial South East region. Until that time, the electricity supply in Rio de Janeiro and Sao Paulo had matched demand with only modest increases in generating capacity.

The first large, modern hydroelectric power station in Brazil, UHE Cubatao, was built in the late 1920s as a response to the drought, and it formed the first phase of the Serra do Mar development. Much of the work on this power station was innovative, as it involved the diversion of the headwaters of the rio Tiete over the great scarp of the Serra do Mar. On completion, in 1926, UHE Cubatao represented the climax of an evolutionary process in Brazil by establishing a sustained interaction between energy and 'progress'. By supplying electrical energy to the fast growing industrial region nearby, the hydraulic projects on the Serra do Mar transformed the great scarp from being a physical barrier to economic growth into a key factor in Brazilian development.

UHE Fontes, built in 1905, comprised one of the largest dams in the world at the time and signified Brazil's constant aim for the superlative - the biggest, the best, (often the worst) - whether talking about hydroelectric power stations, vistas or drivers. But although UHE Fontes on the riberao das Lages was significant due to its civil engineering, the final development of the Lages system in the early 1960s, signalled the end of the era of hydroelectric development close to the industrial centres. Thereafter it was necessary to consider hydraulic sites more distant from the load centres, such as on the rios Parana and Amazonas. Planning had perforce to change from city oriented to river basin oriented.

Each major hydroelectric power project in Brazil, from UHE Fontes to UHE Tucurui, has signified a change in development direction, philosophy or mood.

UHE Paulo Afonso, constructed in the early 1950s, on the rio Sao Francisco was an important project for several reasons. The expansion of this hydroelectric power station was the first instance of water resources planning for power in Brazil. It was the beginning of government participation in the electrical power industry and with the development of the scheme began the process of import substitution in electrical and mechanical equipment manufacture.

At the time of its construction, UHE Tres Marias, built by CEMIG at the end of the 1950s, had the fourth largest earth dam in the world. Construction in the isolated regions of the headwaters of the rio Sao Francisco was difficult, but the regulation afforded by the dam permitted an extra 400 MW of capacity to be installed at UHE Paulo Afonso. UHE Tres Marias itself boosted the local installed capacity by 520 MW and, as a result, stimulated electrometallurgical and electrochemical industries.

UHE Furnas, commissioned in 1963, represented a turning point in the financing of projects. It was the first time that there had been a concentration of resources in a large project. The construction of this large power station afforded the Federal Government its first opportunity to enter the field of electricity production in the South East of Brazil, which had previously been dominated by state and private utilities. The building of UHE Furnas was a move towards overcoming the energy crisis which at that time was crippling the economic and industrial centre of Brazil.

UHE Furnas was considered by the Brazilians as a mark of development success. In energy terms it was a dynamic component of fast escalating development and an indicator of technical achievement. It satisfied immediate needs for additional generating capacity and, simultaneously, established a basis for meeting future demand in the South East as it was part of a larger cascade scheme.

It was instrumental in encouraging the electrical interconnection of the three major industrial cities, Rio de Janeiro, Sao Paulo and Belo Horizonte, regarded as the vertices of Brazil's economic triangle.

Although FURNAS never accepted a philosophy of co-operation with, or aid to Brazilian industry, it was a pioneer of computer optimization of the country's power system, which signified the beginning of a planned approach to river basin development for all uses, not just power.

As an individual project, UHE Itaipu undoubtedly has had the greatest impact on the Brazilian electrical power industry. The full effect of this grand-scale project will not be felt for many years, and its final financial, social and environmental costs remain a subject for conjecture.

UHE Itaipu on the rio Parana, will be the largest hydroelectric power station in the world with an installed capacity of 12.6 GW. This binational project, owned jointly by Brazil and Paraguay, is regarded by the Brazilians as displaying the new, advanced Brazil to the world. All national literature emphasises its grandeur.

However, despite the enthusiastic public relations documentation there has been considerable discord between Brazil and Paraguay over the financing of the construction. Brazil has funded the Paraguayan share and in return is buying back Paraguay's half of the power on very advantageous terms. As a result, Paraguay has insisted that half of the power be generated at 50 Hz, in accord with its own operating frequency, as opposed to Brazil's operating frequency of 60 Hz. Therefore, Brazil has had to transmit some of the power to Sao Paulo by a high voltage direct current link, in order to avoid constructing frequency converter stations.

Not only have international relations with Paraguay been strained as a result of this project, it has also caused a number of disputes with their downstream neighbour Argentina. It is claimed that by using UHE Itaipu as a peaking station it will adversely affect the operation of UHE Corpus, Argentina's own hydroelectric power station on the lower reaches of the rio Parana.

Despite its escalating costs UHE Itaipu has been given government priority; the Federal Government , through ELETROBRAS has maintained that power from the station is essential in order to guarantee electricity supplies to the industrial South East region, but FURNAS, which has had to fund the transmission construction costs and which will be responsible for sale of the power and its distribution, is not convinced. The state utilities CESP and CEMIG have not halted their own hydroelectric power station construction programmes and FURNAS fears that this will lead to a surplus of electrical power in the South East region.

Although there would appear to be major problems associated with UHE Itaipu, the project is noteworthy, from the Brazilian point of view, for more than its size, cost and international problems. It has been instrumental in unifying the Brazilian electrical power industry, and may be regarded as a landmark in the development of Brazil's indigenous electrical power industry.

The process of unifying the electrical power industry was finalised by the Tratado do Itaipu signed in April 1973. This treaty not only created Itaipu Binacional, to co-ordinate the construction of the hydroelectric power station, but it also defined a new structure for ELETROBRAS, the government electricity utility.

Although UHE Itaipu is considered by the Brazilians as a discrete project, a separate entity from the other hydroelectric power stations in the same river basin, the thinking within the electrical power industry is moving more towards integrated river basin development.

Although the rio Grande supports a series of hydroelectric power stations, including UHE Furnas, its development as a cascade system was almost incidental. The site for UHE Furnas was identified for exploitation of its hydraulic potential by a single power station. However, in the cases of the rio Uruguai and rio Amazonas the planned development of the hydraulic potential of these rivers has been in terms of integrated schemes.

The CANAMBRA studies inventoried every site on a 'first-added' basis and in terms of full river development, but such co-ordinated river planning has only now come to the fore with those rivers more distant from the markets. The Uruguai basin has become increasingly important to the industrial South East as its own regional hydraulic potential becomes saturated. However, the reaction from local interests has not been favourable. There has been considerable opposition from the farmers whose land will be inundated and who will not enjoy any benefit from the power. Also, development of the upper reaches of the rio Uruguai is of direct concern to Argentina and Uruguay who are worried about the possible downstream effects which may be experienced in their countries.

The current estimate of hydraulic potential for power in the Amazon basin of 100 GW+ guarantees this region of Brazil as a supplier of abundant renewable energy when technological problems of long distance transmission are overcome. The average population density in this region is only 1.5 persons per square kilometre, and could not warrant exploitation of more than a small fraction of this enormous hydraulic potential.

Although one or two large schemes, such as UHE Tucurui could supply sufficient power in the short term, the tributaries of the Amazon are being considered for total river development. UHE Tucurui is planned as part of a cascade scheme, on the rios Tocantins and Araguaia, and a further cascade scheme is planned on the rio Xingu.

Development of the Amazon region, for power, industry, or cattle ranching, is a controversial subject. The rain forest is a complex and fragile ecosystem which is much less fertile than at first believed. Little is known about it, and even less is understood about the dynamics of the complex interactions between its constituent parts.

Since the discovery of the river Amazon at the end of the fifteenth century, its indigenous inhabitants, the Amerindians, have suffered from the activities of pioneering settlers. They have been variously enslaved, hunted, chased deeper into the forest, removed from their traditional hunting grounds, contaminated with fatal diseases and shot. The forest itself has fared little better when exposed to the unrestrained assault of pioneers.

Commercialisation of rubber, in the 1870s, brought large numbers of peoples to the region. The collapse of the rubber boom fifty years later left large numbers of unemployed people trying to scratch a living in the hostile forest. The main catastrophes which have hit the region, and which have become established, are logging operations, cattle ranching and mineral exploitation. The highway development programme for improving general access and communication has also been responsible for providing access to previously unexploited areas by peasant settlers as well as large scale enterprises. Settlement along the highways and deeper penetration into the forest has been disastrous for the Amerindians as well as to the adjacent environment.

The government agency for indian policy, FUNAI, has adopted the practice of relocating indians in advance of highway development. The same has been true of the hydroelectric development at UHE Tucurui where the Amerindians in the area to be inundated by the reservoir have been uprooted from their 'ancestral' lands. The actual effect on the indians of such relocation can only be guessed at, but previous studies of relocated Amerindians indicates that their future is on the whole bleak. Equally little is known of the long term environmental repercussions of large scale deforestation which is occurring as a result of logging operations, cattle ranching and highway development. However, there is no doubt that many species of flora and fauna have been irrevocably lost and that desertification in some areas could become a serious problem and lead to climatic changes. Exploitation of the forest for timber by foreign enterprises has been done with Federal Government support for the past decade, as extraction of the timber for use overseas has been one method of reducing the foreign debt. Accurate data on the total area which has been cleared is not available.

Although the average population density in the Amazon region is low its actual distribution is uneven, with the bulk of the population resident in a number of towns and cities. The principal of these are Manaus, Santarem and Belem, all on the river Amazon. They are responsible for the bulk of the electricity consumption in Amazonia, comprising only 1.5% of the national total. The lack of large scale industrial enterprises is responsible for this low demand, and the logistics of operating in the region has led to the tendency for the installed capacity to be oil-fired.

With the move towards exploitation of the mineral and other resources, ELETRONORTE maintains that an adequate supply of energy is needed, as this is instrumental in progress. It also believes that regional development should be to the benefit of Brazil as a whole, and this attitude is reflected in the approach taken to energy development along the Amazon.

With the exception of the Hudson Institution's suggestion for a dam on the main river Amazon, little attention was paid to Amazonia's hydraulic potential until the oil crisis of the early 1970s. The costs of fuel and its transportation to the region escalated, and earlier experience of its replacement by combustible solids had been unsuccessful. As a result the answer to future electricity supply was seen to lie with the development of hydroelectric power.

The principal electricity concession areas in the region are mostly associated companies of ELETROBRAS. They are mainly state companies, of which CELPA operates principally in the city of Belem and CEM in Manaus. However, in order to study and operate the exploitation of the hydraulic power in the region ELETRONORTE was created in 1973.

Initially ELETRONORTE continued the work of ENERAM in studying the various hydraulic surveys in the Amazon region, in order to supplement the previously scanty knowledge of hydrological, geological and topographical data. A number of good sites were identified, and some large scale schemes for river basin development were proposed. The principal of these was in the Tocantins-Araguaia basin.

Six hydroelectric stations were given initial priority for construction, the largest of which was UHE Tucurui on the rio Tocantins. This is also the only one under construction at the present time. The two small hydroelectric stations which are now in operation in the Amazon region are the 40 MW UHE Coaracy Nunes and the 10 MW UHE Corua-Una. UHE Coaracy Nunes began operation in 1976 in the state of the Amapa, and UHE Corua-Una has been supplying electricity to the city of Santarem since 1978.

Several other small projects are being re-appraised, but the only spectacularly important project in the region is UHE Tucurui. As the largest hydroelectric power station to be built wholly in Brazil, it will, on completion of the first stage, have an installed capacity of 3.9 GW.

Initial studies of the Tocantins-Araguaia basin were made as early as 1964, yet only in 1973 was the site of UHE Tucurui identified. It was chosen as offering the best possibilities for meeting potential market requirements. However, even with the project well under construction the actual power market has not been well defined.

There is a small domestic and industrial market in the city of Belem, there is a very large industrial market, some 3,000 km away, in the South East, and there are large reserves of bauxite relatively close to UHE Tucurui, which would require large supplies of electrical energy for their processing. The proposal by a Japanese company to construct an aluminium smelter in the region acted as a spur to go ahead with the development of UHE Tucurui. In the event the plan fell through, but the Brazilians still went ahead with the construction of this large and isolated hydroelectric power station.

The power from UHE Tucurui will be used to supply the interconnected system of Belem, the northern region of Goias State, and a number of industrial projects, yet to be established. These will principally involve bauxite processing and iron ore mining. The transmission system of UHE Tucurui will also be interconnected with that of CHESF through the sub-station at Imperatriz. This will permit cheaper hydro-generated electricity to be transmitted from the North East to Belem until UHE Tucurui comes into operation. Thereafter, power from UHE Tucurui will be transmitted to the North East.

Development of the isolated site of UHE Tucurui on the rio Tocantins is one of great technological achievement. Originally only accessible by river, it now possesses an aerodrome and road access - both built by ELETRONORTE. The project has involved not only construction of a hydroelectric power station and transmission network, but also a township for 26,000 people including facilities such as schools, hospitals, a church, recreation centres, a water treatment plant and a small thermal power station.

Everything has had to be brought to the area, mainly up river by barge. All construction materials, contractors' plant, food, clothing and fuel have to be imported from other regions of Brazil, principally the South East some 3,000 km away. The time factor involved is one of months and necessitates very careful planning.

Although the facilities provided by ELETRONORTE are wide ranging there has been discontent amongst the workforce, with an outbreak of rioting in 1980. The old town of Tucurui, 7 km downstream of the construction site, has few facilities, however, and its people have begun to look to ELETRONORTE for help.

Not only does the isolation of the site present problems at the construction phase, it also posed difficulties at the inventory and feasibility stages. Much of the preliminary work on the project has proved to be inaccurate and plans have frequently had to be modified at the execution stage as a result. On the other hand the diversion structure successfully withstood a flood of 60 000 $m^3 s^{-1}$ in 1980, 9 000 $m^3 s^{-1}$ greater than the design flood for the diversion discharge based on a recurrence interval of 25 years.

The principal towns to be directly connected to UHE Tucurui are Belem, Vila do Conde, Tucurui, Maraba and Imperatriz. Some 720 km of transmission line will be constructed between Belem and Imperatriz via Tucurui, much of it crossing heavily forested and swampy terrain.

The effects of UHE Tucurui will be extensive. A reservoir inundating 2,160 km of virgin tropical rain forest will be impounded behind the 11.5 km long dam, which will comprise nearly 5 km of concrete structures with the rest being earthfill dams. Little is known of the area to be inundated. Amerindians live there, although precise data on their numbers is not available. An environmental assessment was undertaken before construction was started, but it appears that little attention is being paid to any of its recommendations.

There is little sympathy shown to those Amerindians and posseiros who will have to be relocated as their land is inundated; there is even less concern on the part of ELETRONORTE towards the destruction of the forest and the flora and fauna which it supports. There is considerable controversy over the best method of dealing with the wood to be found in the area to be flooded. There are no other parallel schemes to turn to for estimates of the extent of the full-ecological damage. In Surinam, Lake Brokopondo has many features similar to those which will be experienced with Lake Tucurui, but they have fundamentally different water retention times which could cause a significantly different effect. Wood clearance plans at Tucurui have been complicated by corruption and delays and little firm information is now available. However, initial moves were made for extraction of the timber, although progress has been erratic.

Although the final cost of the development of UHE Tucurui in financial, human and environmental terms will be high, it will still represent a remarkable achievement in hydroelectric power development in terms of engineering and planning. If, on completion, it is deemed successful it will set the scene for further hydroelectric development in the Amazon, and its final impact will probably be greater than that of UHE Itaipu.

For over half a century all the planning and development initiatives in the Brazilian electrical power industry had been taken by private companies, principally of foreign origin. However, in 1946, for the first time, peak load equalled installed capacity. Thereafter, demand continually outstripped capacity as rapid industrialization resulted in increased demand. The private foreign companies in control of the industry protected their own interests and adopted a disguised rationing policy by repressing demand. This was achieved by delaying the connection of new users to the supply and thus keeping investment in the electrical sector low.

In order to overcome this situation, aggravated by a drought in the 1950s, the Federal Government authorised restrictive measures to reduce consumption of electricity. At the same time, it requested expansion plans to be put forward by the private companies. This was not well received by the foreign enterprises who were not keen to invest money in expansion, blaming the rate problem as a factor in low investment. Considerable argument raged throughout this period between the electricity supply companies and the Government over the rate the suppliers were paid for the electricity.

The very first generator of hydroelectricity in Brazil was an autoproducer, and since that time there has been a significant number in the country. In the early 1950s, when electricity demand could no longer be met, the numbers of autoproducers and their installed capacity increased significantly. The majority using hydraulic energy are to be found in the industrialised states of Minas Gerais and Sao Paulo, and they exert a significant influence on the market of the government concessionires.

In the case of CBA, it considers its own supply to be cheaper and more reliable than that of the state utility, although as an autoproducer it is not allowed to sell any of its power and must make compulsory energy purchases from 'The Light' at nearly four times its own generation cost. In some instances autoproducers must pay a compulsory loan of 32.5% of the fiscal tariff, which is only recoverable after 20 years. Even so, autoproducers still consider the capital expenditure an acceptable economic proposition.

The establishment of autoproducers in the Brazilian electrical power industry was not the only response to deficiencies in electricity production. It precipitated government intervention in the industry. The first state government participation was in Rio Grande do Sul, where the CEEE was created in 1943 in order to develop and operate a general electrification plan for the entire state.

CEEE was closely followed by CHESF, which had Federal Government backing to develop the middle reaches of the rio Sao Francisco around Paulo Afonso, in order to try and alleviate some of the problems of supplying electricity to the North East region.

CEMIG, the state utility created by the government of Minas Gerais, in 1952, successfully answered the need for an expansion of electricity supply caused by rapid regional industrial development, which was being strangled by an inadequate supply system. As a result of CEMIG's immediate building programme, adding a further 168 MW to the system in four years, industrial development of the state was able to accelerate, bringing political power and wealth to the region, as well as a large and diverse industrial base. CEMIG was also a pioneer of rural electrification, although, taking Brazil as a whole, this activity cannot be rated as one of the most successful of the Brazilian electrical power industry.

Although CEMIG still wields considerable power, its Sao Paulo state equivalent, CESP is more influential. This is primarily because Sao Paulo state is the major economic and industrial centre of Brazil. However, in the 1950s it was feared that the rapid economic development of this state would be threatened by a lack of electrical power. The situation was alleviated by the creation of a number of mixed economy enterprises to ensure exploitation of the available local hydraulic resources. These enterprises were eventually amalgamated in 1966 to form the powerful state company CESP.

The ultimate in governmental participation in the Brazilian electrical power industry came with the creation of ELETROBRAS in 1962. It is a corporation backed up both Federal Government and private capital, and is responsible for the overall planing, financing and co-ordination of the whole Brazilian electrical power industry.

In 1960, the Federal Government had placed administration of Brazilian energy policy in the hands of the MME. Whose role was, and remains, one of fundamental economic, social and political importance in that it has continued to be responsible for the exploitation of national energy and mineral resources.

In 1965, re-organisation of the MME resulted in the creation of a new division, the DNAEE, which was to plan, execute and co-ordinate hydrological studies. It also has the responsibility for granting of concessions to build power stations and establishing electrical power rates. It is ELETROBRAS, however, which is the principal instrument of the MME in directing the electrical power industry.

Although ELETROBRAS was not created until 1962, a decree establishing broad guidelines for the development of the available hydraulic potential was passed in 1904. It then took until 1934 for the Codigo de Aguas to come into force which outlined the use of national water resources and gave a sense of unity to the electrical power industry. However, a further 23 years elapsed before there was full legal regulation of the activities of those organisations subject to the code.

Such tardiness in legally defining the operations of the electrical power industry had resulted in its decline, and at the time of the appearance of ELETROBRAS on to the scene, there was stagnation of private initiative in the industry. This had been exacerbated by restrictions due to the Codigo de Aguas and problems of importation of equipment.

The creation of ELETROBRAS was not welcomed by the private electricity utilities, but this has not prevented it from progressively, and irreversibly, absorbing national and foreign electricity enterprises. As a holding company and nucleus of a group of concessionaires ELETROBRAS has given the Brazilian electrical power industry both an administrative continuity and the ability to develop long term planning programmes.

ELETROBRAS is the legal organ through which the Federal Government acts on matters electrical, and as a financing agency supporting its subsidiaries and other electricity companies, it is responsible for the co-ordination of foreign investment programmes. In practice, the company operates through four regional subsidiaries - FURNAS, CHESF, ELETROSUL and ELETRONORTE, and three distribution utilities - CEM, ESCELSA and CBEE. It is also the major shareholder in 'The Light' which was purchased by the Brazilian government from its Canadian holding company, Brascan, in 1979.

FURNAS and CHESF were both operational before the creation of ELETROBRAS. Whereas CHESF benefitted from this, as the new company shouldered some of its responsibilities giving CHESF greater financial freedom to undertake the construction of new power stations and transmission lines, FURNAS lost its primary role of a planning agency to ELETROBRAS.

ELETROSUL was created in 1968 by the merger of the existing utilities in the rural South region. Although it is still primarily rural, it is of increasing importance, in the energy sense, as it is to the hydraulic resources of the South which the industrial South East is now looking for its electrical power. As long distance transmission becomes more economic, ELETROSUL has a greater part to play in national electrification; there is already an inter-regional link between the South and South East via the Itaipu transmission system.

ELETRONORTE, the most recent of the ELETROBRAS subsidiaries, which came into existance in 1972, has, as yet, no self-constructed installed capacity. It was created in order to exploit the hydraulic potential of the rio Tocantins and to build UHE Tucurui. Part of its role is to continue the systematic study of the hydraulic potential of the Amazon tributaries as begun by ENERAM.

As in the case of ELETROSUL, ELETRONORTE can expect to grow in importance as the economic and industrial centres turn to the enormous hydraulic potential of the Amazon region as that in the rest of Brazil becomes fully exploited. At present its principal markets are domestic and commercial in nature, but with increased installed capacity it is hoped to attract industry to the region.

As a result of the lack of infrastructure, terrain and climate, much of ELETRONORTES's work in the Amazon region has to be of a pioneering nature. At the same time it has to be heavily subsidised by Federal Government funds, not only to help it bear the financial burden imposed by the construction of UHE Tucurui, but because it has no ready source of income due to not generating electricity for sale.

'The Light' is the largest, and most important, of the distribution utilities which comes under the jurisdiction of ELETROBRAS. It was the last major foreign utility in Brazil, and it was purchased because its services had deteriorated. This was fairly typical and was the result of the long standing inadequate investment by foreign companies in the industry. Although the company is now primarily a distribution utility, it does possess its own installed capacity. However, its power stations rarely run at full capacity as it is compelled to purchase electricity from FURNAS and CESP.

CEPEL is not an electricity utility. It was created by ELETROBRAS in 1974, and is directly subordinate to it, and also responsible to the four subsidiaries. CEPEL stems from Brazil's need to develop the technology applicable to electrical systems and equipment, and its brief is to provide an infrastructure for scientific research and to advance technology in the fields relevant to the electricity utilities. One of its recent projects has been concerned with the optimisation of energy planning.

As the optimum size for hydroelectric power stations increases with a corresponding increase in capital expenditure, the state companies, such as CEMIG, have required Federal Government backing. As CEMIG and CESP continue constructing large hydroelectric power stations to supply power to the industrial South East, their strong influence remains little diminished. CEMIG is indirectly responsible for much of the outlook of the present day Brazilian electrical power industry as it has been a training ground for many of the top men in the state utilities.

Itaipu Binacional, created in accordance with the Tratado de Itaipu in 1973, is not a subsidiary of ELETROBRAS, but its directorate comprises members of ELETROBRAS and its Paraguayan equivalent, ANDE. It is responsible for the construction of UHE Itaipu.

The treaty not only defined the activities of the ELETROBRAS subsidiaries and their concession areas, it also redefined the internal structure of ELETROBRAS. It also created the GCOI, a power council which is to co-ordinate the distribution of power from UHE Itaipu to the South East and South regions. The council, which includes representatives of various state utilities and some of the ELETROBRAS subsidiaries, co-ordinates the national interconnections. For this reason, ELETRONORTE is not included because at present it does not generate electricity.

Although the structure of the GCOI mirors that of the operations directorate of ELETROBRAS, its principal function is interconnection between regions, and it has been responsible for the electrical links between the South and South East regions. ELETROBRAS is sub-divided into a number of directorates which organise certain sectors of the Brazilian electrical power industry such as regional integration, finance and economics, operations, planning and engineering, and co-ordination.

Each directorate is sub-divided into departments, which in turn are sub-divided into divisions and sub-committees. These cover all facets of the work of the electrical power industry including market, load forecasting, environmental issues, maintenance and economic planning. As part of the supervisory process the day-by-day operations of all the power stations are monitored.

Once UHE Itaipu and the nuclear power stations at Angra dos

Reis are operational, the Brazilian electrical power system in the economic centre of the country will be more sophisticated as there will be greater scope to deal with problems, such as periodic low rainfall and sudden peak power demands, as the integrated generating capacity will be operated with a greater inherent flexibility.

UHE Itaipu can be regarded as a unifying influence in the Brazilian electrical power industry by stimulating inter-regional connections and heralding the creation of the GCOI. None of this could have occurred if a national transmission frequency had not been first established.

As we have seen, the electrical power industry of Brazil was set up piecemeal by a number of private and public, foreign and national companies, using equipment from a variety of sources. Thus a non-integrated electrical power industry spontaneously developed with different systems operating at several different frequencies. The need to unify the frequency arose from the need to optimise the use of energy resources. The first move in this direction was made as early as 1938 but nothing happened until 1954, when a proposal was made to adopt 60 Hz as the national standard. However, three years later, a dual standard using the 50 Hz and 60 Hz was adopted, and it was not until 1964 that a single frequency of 60 Hz was formally designated as the national frequency. The changeover, however, scheduled for completion in 1971 took until 1977 and, it was not until then that widespread regional interconnections became possible.

The 1960s were the years when effort was made to consolidate the power industry. These years saw the creation of ELETROBRAS and the adoption of a single operating frequency; they were also witness to the first attempts at planning within the industry.

After the commissioning of UHE Furnas in 1963, some of the utilities changed their role from that of bulk suppliers to generation and transmission utilities. Distribution was left to other enterprises. It was into this unstructured system that the foreign consortium CANAMBRA was invited to survey the hydraulic resources of the South East and the South regions of Brazil.

The study carried out by CANAMBRA included an evaluation of the electrical power sites, an inventory of hydraulic sites, feasibility studies of selected sites, re-organisation of regional hydrometric services, a power market forecast to 1980, including a generation and transmission programme, survey of transmission and distribution requirements, and an evaluation of frequency conversion needs.

In the inventory studies, the potential hydroelectric sites were tabulated using economic criteria as the primary basis of selection. Any sites which appeared attractive were then subjected to a feasibility study.

Little suitable data was available for CANAMBRA to use. There were few topographical or geological maps, and hydrological data were scanty. The consortium organised the first Brazilian aerial survey for the purpose of its inventories. Three types of project were studied - power, storage, and power plus storage, and no allowances were made for expansion of generating capacity or supply of facilities such as navigation. However, the indirect costs considered were those of the camp and construction plant and their operation and maintenance, and the administration and engineering costs.

It was expected that all projects studied would involve some form of foreign equipment, hence the CANAMBRA estimates of costs consisted of two currency elements. All equipment and services available in Brazil were costed in cruzeiros, and those to be obtained from overseas were costed in US dollars. The crizeiro portion was assumed to be 75% of the total cost. As a guideline, CANAMBRA adopted a lower inventory limit of minimum capacity of 10 MW and, as upper limit, an installation cost of US $ 500/kw.

The procedures now used follow many of the CANAMBRA guidelines, in that inventory and feasibility studies are still carried out. Further guidelines issued by ELETROBRAS's Diretoria e Planejamento e Engenharia identify the development needs, and the instruments and criteria for planning.

* * *

The major problem which has to be faced today is that of expansion of generating capacity. Most of the hydraulic potential close to the load centres has been exploited and it has become necessary to look to hydraulic resources distant from markets, thus requiring transmission of large blocks of energy over large distances. There is still the option of construction of some very small hydroelectric power stations close to areas of demand, but ELETROBRAS and its subsidiaries have tended to concentrate on the larger, more distant projects.

Three planning stages have been adopted - long, medium and short term planning, as ELETROBRAS considers the perspectives for medium and long term planning in the Brazilian electrical power industry to be quite distinct. In the medium term, it considers the choice to lie between hydroelectric development as close as possible to the load centres, or the use of coal or nuclear energy as electricity sources. In the long term, the problem is seen as one of the degree of technological development required, principally in terms of energy transfer from the Amazon region and the development of nuclear power.

Foreign consultants were instrumental in starting Brazil's steps in planning the electrical power industry. But, in time, FURNAS developed a methodology and criteria more appropriate to the Brazilian situation. In Brazil, the principal determinant of expansion of the electrical power system is the growth of demand, and the long term forecasting of this power market uses a single reference which is based on the likely increases of economic activity and the population.

A long term plan permits the identification of the principal lines of development of a system. In Brazil, a thirty year horizon is used to determine the optimal economic participation which characterises the main lines of necessary technological and industrial development, as a function of minimum programmes of improvement.

Planning horizons of 20 to 30 years are necessary in Brazil in order to identify the hydraulic potentials and river basin developments which are distant from the markets. Decisions to build large generating plants have a lead time of eight years (for main transmission the time from planning to operation is reduced to three years) hence it is necessary to analyse the requirements which need to be met over at least fifteen years so as to guarantee that they are met on time. As most of the expansion of Brazilian generating capacity is by means of very large plant, such long lead times are likely to continue to be necessary.

In the long term, the Brazilians believe that nuclear energy will become their second major energy source, after hydroelectricity. Of fundamental importance to this consideration are the prospects, in Brazil, for the use of new technologies including fast breeder and thorium reactors. For the hydraulic potential of the Amazon to be tapped there must also be further technological advances for the transmission of large blocks of energy.

The vast hydroelectric potential available in Brazil is the most important aspect of any of its expansion plans, with long distance, high voltage transmission being a feature in the electricity supply. Indigenous coal is comparatively little used as an energy source for electricity production because of its low quality. In the overall planning perspectives it is not considered as favourably as hydraulic and nuclear energy sources. Its principal use is for thermal complementation in periods of low hydrological flows.

The aim of the Brazilian electricity supply industry is to convert other forms of energy to electricity in order to maintain a continuous supply at a stable cost. Therefore, when making market projections, an estimated security margin is adopted, so that the final value used by the Brazilians in estimating demand is the probable market plus the security margin. This security margin is progressively reduced as interconnection and integration leads to higher operating flexibility.

Until the Brazilian electrical power industry achieved some form of integration, it had to base its forecasts and select its projects on non-standard reference data. However, the DEME now publishes economic reference data, and ELETROBRAS publishes the "Orcamento Plurianual do Setor e Enercia Eletrica" which summarises the necessary information for estimate of investment resources over a five year period. As a result, project selection is more refined and system integration is better planned. However, the forecasts used contain long term uncertainties and can only give probable values for each year when estimating future demand. In addition, the wide geographical dispersion of the load centres requires detailed forecasts to be made at a regional level.

Other uncertainties inherent in long term planning are the relationships between the various costs. For example, hydroelectric power stations have a higher capital cost and lower operational costs than conventional thermal stations, but over a thirty year period the precise relationship between these costs could (and have) changed considerably.

Whereas the long term analysis carried out by the Brazilians indicates the general lines of development of their electrical system and establishes the generation projects and principal transmission trunks, in the medium term the plans are considered in greater detail. There is increased precision in the information on physical characteristics, construction periods and costs.

Using the long and medium term projections, Brazil devizes short term plans for the electrical power industry. It evolves a plan of action incorporating recommendations for the finacing of the short and medium term programmes and for legislative changes. It also defines studies necessary for the improvement of the long, medium and short term analyses.

As the bulk of Brazilian electrical power is of hydraulic origin, and as there is little over capacity the electricity supply is not constant. It largely depends on the randomness of river flows, and as a result the supply criteria adopted have dictated that in the case of critical hydrological conditions there will be a deficit in supply.

Computational models have been developed in order to calculate the probabilities of occurrence of critical hydrological conditions, and computer simulation models are used to determine the various alternatives for expansion of the system, using cost/benefit indices. Most of the operational models are used in order to analyse the use of water resources for power, although conventional thermal power stations could offer a more flexible choice of operating policy.

Over Brazil, as a whole, 81% of the installed capacity is driven hydraulically. It is only in the Amazon that thermal generation is more common - a situation which will change with the commissioning of UHE Tucurui.

Ever since the 1890s, it has been the case that hydroelectric power has always been the major source of Brazilian electrical power. During this period the early hydroelectric stations, with outputs measured in kilowatts, have been replaced by the computer controlled gigawatt complexes of today.

* * *

Conclusions

Brazil has had an electrical power industry based on hydroelectric generation since 1883; and it has been at the forefront of hydroelectric power development since then. From this study, a number of conclusions may be drawn from the hydroelectric power experience in Brazil.

(i) The dominant factor in the development of Brazilian hydroelectric power has been the parallel development of Brazilian industry. Over the past century the two have gone hand-in-hand, and have been responsible for general urban development.

(ii) The industrial sector has been the most dynamic in the Brazilian economy since the second World War, with the adoption, by Brazil, of the energy intensive consumption patterns of the western industrial countries. This has been possible because of the parallel dynamism of the electrical power industry, which with the exception of one period of low investment, has remained buoyant. The South

East was the centre of the post-war economic boom as its good electricity supply led to industrial expansion. In particular the Kubitschek government gave priority to this industrial expansion.

(iii) In developing its hydraulic potential Brazil has successfully exploited what is probably its greatest natural resource - a renewable energy source. Until recently, the development of hydroelectric power in Brazil has often been in advance of the development of other Brazilian resources, but in line with general prevailing conditions. However, the current world economic recession together with Brazil's balance of payments problems have changed this; the recent hydroelectric projects of UHE Itaipu and UHE Tucurui have become heavy financial burdens on the Federal Government.

(iv) The world oil crisis in the early 1970s, despite its recessionary effect, was a great boost to Brazilian development of hydraulic potential and resulted in accelerated project development. It also stimulated involvement in nuclear technology and experimentation with alcohol substitution for petroleum products.

(v) Future development of Brazil's energy resources will depend on advances in technology. As the hydroelectric potential in the industrial South East has been almost fully exploited, primary energy for future installed capacity will either have to be of nuclear origin in that region or of hydraulic origin in the Amazon region with long distance transmission.

(vi) The current aim of the Brazilian electrical power industry is to meet the country's electricity needs, principally by hydraulic means, whilst ensuring that expansion of the power industry is compatible with the market requirements. This involves long term forecasting, of both demand and financial requirements, and is being undertaken using computational methods. As data is scanty, and demographic and financial trends uncertain, it is proving difficult to identify specific projects which will match market needs. The over capacity, at both UHE Itaipu, in the South, and UHE Tucurui, in the North, indicates the extent of the errors in forecasting.

(vii) The greatest single factor in the creation of the current perspective of the Brazilian electrical power industry was probably the standardization of the operating frequency to 60 Hz; it led to the possibility of inter- regional connections and national energy planning.

(viii) Government participation in the Brazilian electrical power industry was stimulated as a result of poor investment in the industry by the foreign utilities, who operated the sector until the 1960s, which resulted in repressed demand.

(ix) The objective of ELETROBRAS is to meet all Brazil's electrical needs whilst ensuring compatibility between expansion in the electrical sector and consumer demand.

(x) Since the State and Federal Governments became instrumental in the operation of the Brazilian electrical power industry the method of financing of projects has become to depend on foreign capital. As the economic situation in Brazil has worsened, this has led to a severe balance of payments problem which has resulted in non-priority projects being shelved and others, such as UHE Itaipu and UHE Tucurui, being delayed. This problem, coupled with rapid inflation and hourly changing exchange rates for the cruzeiro against the dollar, makes meaningful discussion of financial costs of such projects impossible. Suffice it to say that they are proving very expensive to build. The major costs for UHE Itaipu are the interest costs, comprising nearly one third of the total construction costs.

(xi) The state utilities have shaped the current picture of the Brazilian electrical power industry. Of these, CEMIG, although not the most powerful, has had the greatest influence. Not only did it identify the Furnas site, it has been the training ground for many of the most influential men in the industry today. In the opinion of some, it has surpassed the frontiers of an electricity utility by establishing itself as a development agency.

(xii) With government participation in the electrical power industry, in the form of ELETROBRAS, national planning became possible. However, this planning procedure is complicated by the fact that Brazil is still planning for massive expansion in addition to coping with obsolescence, together with allowances for improvements and small scale expansion. This may be contrasted with the situation in most industrial countries with low population growth rates.

(xiii) Unlike some other developing countries, Brazil has reaped positive benefits from the development of its hydraulic power. The majority of its schemes run smoothly and efficiently and, in terms of the large area of land inundated by reservoirs, the environmental effects of completed schemes, to date, have not been disastrous. The main positive benefits include raised levels of direct and indirect employment. Improved living conditions and, in some cases, improved housing and facilities such as hospitals.

(xiv) Negative effects experienced as a result of hydroelectric power development include the indirect effect of an increased migration of rural agricultural workers to the urban slums in search of work as industrialization has increased, and relocation of small scale farmers and Amerindians from their traditional lands with little recompense.

(xv) Of the individual hydroelectric power stations, both UHE Itaipu and UHE Tucurui are worthy of mention. Although neither is fully operational, and little can be concluded about their final impact on Brazil, UHE Itaipu has been instrumental in unifying the Brazilian electrical power industry, and UHE Tucurui, one of the most ambitious projects to be undertaken in the world, will, for good or bad, have extensive environmental ramifications.

(xvi) Only in recent years has attention been paid to the environmental effects of reservoirs behind dams, and to multiple use of these reservoirs. To date Brazil appears to have been fortunate in suffering no major ecological disasters.

(xvii) Whatever lessons are learnt from UHE Tucurui, large scale hydroelectric power development of the Amazon basin will remain controversial. Substantial reservoirs flooding large tacts of tropical rain forest, containing many thousands of species of flora and fauna and displacing indigenous Amerindians, will always be an emotive subject for discussion. However, it is clear that, given adequate financial resources, Brazil will exploit this region for power, for in the long term it is the only option open, unless objections to nuclear power are overcome.

* * *

General Conclusions

Brazil differs from other developing countries in that it has a well established urban middle class with a high level of scientific and technological skills, coupled with experience at using these skills. This factor alone makes it difficult to draw any direct parallels between the Brazilian experience and other hydroelectric power developments in the Third World. Similarly the presence of large urban and rural poor sectors of the population, many living without the benefit of electrical power makes direct comparison with western industrial nations difficult.

Not only does the unique combination of factors present in Brazil make comparisons difficult so do those relevant to hydroelectric power development. Not only is the provision of electricity for consumption as much affected by the availability of natural resources as by political, economic and institutional factors, but the building of hydroelectric power stations differs from other construction projects in that each design is site specific and no two hydroelectric power stations are the same.

Nevertheless, a number of broad general conclusions may be made about the development of hydroelectric power in Brazil.

(i) Brazil has a well developed system of hydroelectric power stations, and the general direction taken by the country's hydroelectric power development, until the 1970s, could profitably be copied by some of the developing nations. It was a gradual development of indigenous hydraulic potential for power in accordance with the industrial and commercial markets. The growth of the power industry stimulated growth in these markets, and vice-versa. The two, more or less, developed together, avoiding a great build up of surplus capacity or deficit in supply. At each stage the Brazilian projects were to the limits of available technical expertise and financial resources, without being too ambitious. On the whole they have provided reliable supplies of power without serious deleterious effect.

(ii) To date most of the hydroelectric power developments in Brazil have comprised individual projects and have not been part of a wider scheme, although a number of cascade developments now exist or have been planned. However, these have been purely for power and there has been no attention paid to integrated river basin planning as by the Tennessee Valley Authority in the USA.

(iii) With the unification of frequency, Brazil now undertakes national energy planning, and has developed its own planning criteria. From this country, where rural electrification is poorly developed and where regional interconnection has only recently become a reality, these criteria are more applicable to other developing countries than to those used in North America and Europe.

(iv) Brazilian hydroelectric power stations appear to have been remarkably free of many of the problems which have beset other such stations in the Third World. This is presumably because of the core of technical expertise available, the fact that projects (until recently) have been pioneering, but not over ambitious, and that many of the actual hydroelectric power stations have been in regions of low population density and sub-tropical climate.

(v) Resettlement problems have been experienced in Brazil, but these have been little publicised and, on the whole, have not been major. Again, most of the common waterborn diseases are endemic in Brazil, but there is lack of substantial documentation in this problem which would indicate that health problems associated with Brazilian impoundment of reservoirs for power are either few (they are not in the tropics) or not well studied.

(vi) The more recent, and 'grandiose' projects, appear to have more similarities to some of the African projects. Both UHE Itaipu and UHE Tucurui will supply power surplus to forseeable market requirements, and they have both placed a severe financial burden on the Brazilian Government. However, both provide an example of co-ordination of planning, construction and operation of large hydroelectric power stations in isolated situations, and will give insight to the civil and mechanical engineering required for similar large scale projects elsewhere.

(vii) Without a doubt, whether it is a success or a failure, UHE Tucurui will provide information on the inundation of large tracts of tropical rain forest. It will provide an excellent opportunity for the study of reservoir impoundment under tropical rain forest conditions and longer term ecological impacts.

(viii) The future perspective of the Brazilian power industry is strongly coloured by long distance transmission. Transmission from Itaipu is over an HVDC link, and improved technology as developed by Brazil will have world wide application.

* * *

Prognostication

From the work contained in this thesis it is apparent that there is a large number of potential aspects of the electrical power industry of Brazil which would benefit from further study. At the present time a number of far-reaching power projects are in the construction phase - UHE Itaipu, UHE Tucurui and the nuclear power stations Angra I and II. Technical difficulties with long distance transmission are being overcome, new planning methodologies are being adopted, and there is a growing awareness of environmental effects (719).

Some of these projects are approaching completion such as UHE Itaipu (720), other are suffering financial problems (721), especially as the economic climate in Brazil is rapidly worsening, with galloping inflation and multi-million dollar loans on which the country is having difficulty maintaining the interest payments (722).

There are several aspects of UHE Itaipu which would benefit from further study. There is controversy over whether its power is really necessary for Brazil. If the state utilities such as CESP and CEMIG cannot be disuaded from constructing their own gigawatt power stations then the south east of Brazil will have a surfeit of excess capacity. This will turn Itaipu into a large white elephant - a status that it must, already, have in Paraguay. Studies are already in progress on the economic and social impact of UHE Itaipu on Paraguay, but a similar study of its effect, once operational, on Brazil would give an insight into whether Brazil's policy of "the largest in the world" has paid dividends or brought disaster.

Certainly UHE Itaipu has done much towards unification of the Brazilian electrical power industry, but how much impact has the share of UHE Itaipu's power had on the relatively non-industrialised South Region, receiving its share through the substation at Ivaipora? It appears that its impact will be felt more by improving domestic and commercial supplies in this region rather than inducing rapid industrialisation. However, in the case of a surfeit of power in the South East, more of UHE Itaipu's may be diverted to the South thus delaying the controversial hydroelectric development of the rio Uruguai.

UHE Itaipu is the first large scale Brazilian project to be subject to the policy of indigenisation, as the bulk of materials and equipment had to be of Brazilian design and origin. Once UHE Itaipu is fully operational and has been so for a reasonable period, it would be interesting to do a comparative study between its operational progress and that of smooth-running UHE Furnas, which was built using foreign expertise and equipment.

The Brazilians possess a high level of technical ability but, in a project of such enormity as the 12.6 GW UHE Itaipu, there remains some doubt as to whether the indigenisation policy will have been successful, or whether the technology nationally available was not sufficiently adequate to cope with the size of the project. Personally, I think that skilled as the Brazilians are, there will be problems, probably not of an insuperable nature, as a direct result of the innovative nature and shear size of the project.

UHE Tucurui, another Brazilian hydroelectric power station, with a large capacity and not too well defined market, presents a number of obvious areas for further study. The most immediate consideration is the environmental impact of the 2,160 km lake behind the 7 km long dam. There has already been considerable controversy over the clearance of the tropical rain forest. After reputed embezzlement of pension fund monies and use of defoliants (723) it appears that the vegetation is to be left to rot in the waters of the reservoir. No one is certain, under these conditions what the outcome will be but whatever it is, a study of the limnology, fish, incidence of waterborn parasites and proliferation of water weeds would be beneficial.

The contentious issue of the displaced Amerindians certainly warrants study, as those moved to other reserves are likely to suffer social degradation. However, access to relevant information, if it exists, may be restricted or difficult of access. Depending upon the condition of the water, the lake could become a focus for new social groups and the power may improve local industry, and thus reduce the level of poverty in towns such as Maraba.

If the aluminium industry, utilising bauxite from the Trombetas region, does develop to any extent it is likely to require only the power from UHE Tucurui. Unless the world market for aluminium recovers, the extra power from the other proposed stations in the cascade scheme will not be necessary. Large scale industrialisation of the area is unlikely as it is too isolated and the climate too hostile. However, it is possible that with improved long distance transmission, the power from the Amazon region could be used in the industrial South East, although in the shorter term, further hydroelectric power development in South Brazil would present fewer problems both in terms of working environment and transmission distances.

If UHE Tucurui does present serious problems, with acidic reservoir water for example, then this may prevent hydraulic development of the rio Xingo, which would have a controversial, but almost certainly, detrimental affect on the many Amerindians in the region. It will be interesting to wait and see whether the Brazilians will be content to wait to learn lessons from UHE Tucurui before embarking on further large hydroelectric power developments in the Amazon Basin. Studies of this nature could, however, be clouded by the current economic climate which will probably delay the initiation of any proposed projects. However, a study of power planning for the Amazon region and how this has been affected by the interaction of environmental and engineering problems, as recorded at Tucurui, and the Brazilian economic status should yield an insight into Brazilian mentality and how this has changed over the years.

Both UHE Itaipu and UHE Tucurui will have a marked social impact on their areas of location; not just on the peoples displaced by the reservoirs but on the townships of tens of thousands of people established in the construction areas, with access to reasonable facilities such as hospitals and schools. Brazil has built such townships for earlier projects, but not of the size or isolation as at Foz do Iguacu and Tucurui. Few of the employees will be needed once the power stations are operational - where will the rest go? Will they flock to the industrial centres of the South East or back to the drought-ridden North East, or will they remain in the townships, scraping a living however they can? Traditionally, many of these workers are migrant workers, moving from project to project, but with the Brazilian economic crisis delaying the initiation of new projects, there is little hope of immediate new employment. These aspects present ample scope for a detailed social analysis of the impact of these two large projects on the workers' past, present and future livelihoods.

In the last decade, the Brazilian electrical power industry has become to be planned as an entity, using modern computational techniques and methodology. However, much forward planning depends on predictions of the future. The demographic and economic assumptions are presented in detail in the literature. There is, therefore, scope for study of the planning perspectives as adopted by Brazil for its electrical power industry and how they have correlated with the situations as they have actually arisen. Have the demographic assumptions been correct, have they reflected actual demand and how has the planning had to be modified in the face of the shortage of funds for building new power stations?

Finally, no picture of the future Brazilian electrical power industry is complete without a study of the nuclear question. Will

Brazil turn to nuclear power, or will improved technology for long distance transmission from hydraulic sites preclude this? Do the planning perspectives reflect any change in attitude towards nuclear power, and its supposed necessity for technological advance or proliferation of nuclear weapons, or show a preference for hydroelectric power using long distance transmission? When the data to answer these questions accumulates further insight will be gained into the evolution of the Brazilian idea of "progress".

Appendix 1 - Acronyms

ALBRAS	Aluminio Brasileiras
ALUNORTE	Alumino do Norte
AMFORP	American Foreign Power Company
AMZA	Amazônia Mineração S/A
ANDE	Administracion Nacional de Eletricidad
BELSA	Bandeirante de Eletricidade S/A
BNDE	Banco Nacional de Desenvolvimento Econômico
BRDE	Banco Regional de Desenvolvimento do Extremo Sul
CAEEB	Companhia Auxiliar das Empresas Elétricas Brasileiras
CANAMBRA	Canambra Engineering Consultants Limited
CBA	Companhia Brasileira do Aluminio
CBEE	Companhia Brasileira de Energia Elétrica
CCC	Conta de Consumo de Combustiveis
CEA	Companhia de Eletricidade do Amapá
CEARP	Comissão de Estudos e Acompanhamento do Rio Paraiba
CELETRAMAZON	Centrais Elétricas de Amazonas
CELG	Centrais Elétricas de Goías
CELPA	Centrais Elétricas do Pará
CELUSA	Centrais Elétricas de Urubupunga
CEM	Companhia de Eletricidade do Manaus
CEMAT	Centrais Elétricas de Mato Grosso
CEMIG	Centrais Elétricas de Minas Gerais
CEPEL	Centro de Pesquisas de Energia Elétrica
CEPIC	Comissão de Estudos de Programação de Intercambios e sua Contabilização
CER	Centrais Elétricas de Roraima

CERON	Centrais Elétricas de Rondônia
CESP	Centrais Elétricas de São Paulo
CHERP	Companhia Hidrelétrica do Rio Pardo
CHESF	Companhia Hidrelétrica do São Francisco
CIBPU	Comissão Interstadual da Bacia do Paraná-Uruguai
CIEM	Consorcio Itaipu Eletromecânico
CIVAT	Comissão Interstadual dos Vales do Araguaia-Tocantins
CNAEE	Conselho Nacional de Águas e Energia Elétrica
CNEC	Consorcio Nacional de Engenheiros Consultores S/A
CNEN	Conselho Nacional de Energia Nuclear
CNP	Conselho Nacional de Petroleo
CNPq	Conselho Nacional de Pesquisas
COMAM	Comissão de Analise do Mercado
COMEPA	Companhia de Melhoramentos de Paraibuna S/A
CONEMPA	Consorcio de Empresas Constructoras Paraguayas SRL
COPEL	Companhia Paranaense de Eletricidade
CPFL	Companhia Paulista de Força e Luz
CPRM	Centro de Pesquisas de Recursos Minerais
CVRD	Companhia do Vale Rio Doce
DAEE	Departamento de Águas e Energia Elétrica
DECOFRE	Departamento de Conversão de Frequência
DEME	Departamento de Estudos de Mercado
DENE	Departamento de Estudos Energéticos
DEOP	Departamento de Operação Energético
DNAEE	Departamento Nacional de Águas e Energia Elétrica
DNPM	Departamento Nacional de Produção Mineral
DNPVN	Departamento Nacional de Portes e Vias Navigaveis

DVEO	Divisão de Engenharia de Operação
DVON	Divisão de Operação Energético
ELETROACRE	Centrais Elétricas de Acre
ELETROBRAS	Centrais Elétricas Brasileiras S/A
ELETRONORTE	Centrais Elétricas do Norte do Brasil S/A
ELETROSUL	Centrais Elétricas do Sul do Brasil S/A
ENERAM	Comitê Coordenador de Estudos Energéticos da Amazônia
ENERNORDE	Comitê Coordenador de Estudos Energéticos da Região Nordeste
ENERSUL	Steering committee, South Brazil
ERMIG	Eletrificação Rural de Minas Gerais S/A
ESCELSA	Espirito Santo Centrais Elétricas S/A
FFE	Fundo Federal de Eletrificação
FINEP	Financiadora de Estudos e Projetos
FUNAI	Fundação Nacional do Indio
FURNAS	Centrais Elétricas de Furnas S/A
GCOI	Grupo Coordenador de Operação Interligada
GDP	Gross Domestic Product
GNP	Gross National Product
GTEH	Grupo de Trabalho de Estudos Hidrológicos
GTEN	Grupo de Trabalho de Estudos Energéticos
GTMC	Grupo de Trabalho de Metodologia e Criterios
IADB	Inter American Development Bank
IBGE	Fundação Instituto Brasileiro de Geografia e Estatística
IBRD	International Bank for Reconstruction and Development (World Bank)

INCRA	Instituto Nacional de Colonização e Reforma Agraria
INPA	Instituto Nacional de Pesquisas da Amazônia
INPE	Instituto Nacional de Pesquisas Espaciais
IUEE	Imposto Único sobre Energia Elétrica
LMSA	Light Metal Smelter's Association
MME	Ministerio de Minas e Energia
NASA	U.S. National Aeronautics and Space Administration
NUCLEBRAS	Empresas Nucleares Brasileiras S/A
PETROBRAS	Petróleo Brasileiro S/A
PIN	Programa de Integração Nacional
PNA	Programa Nacional do Álcool - Proálcool
SCEN	Sub-comitê de Estudos Energéticos
SNIEC	Sindicato Nacional da Industria de Extração do Carvão
SPVEA	Superintendência para a Valorização Econômica da Amazônia
SUDAM	Superintendência de Desenvolvimento da Amazônia
SUFRAMA	Superintendência da Zona Franca de Manaus
UHE	Usina Hidrelétrica
UNDP	United Nations Development Programme
UNICON	União de Construtoras Limitida
USELPA	Usinas Elétricas do Paranapanema S/A
UTE	Usina Termelétrica

Appendix 2 : Dollar - Cruzeiro Exchange Rate

Values given are the numbers of cruzeiros to the US dollar.

December	1964	1.850
"	1965	2.220
"	1966	2.220
"	1967	2.715
"	1968	3.830
"	1969	4.350
"	1970	4.950
"	1971	5.635
"	1972	6.215
"	1973	6.220
"	1974	7.435
"	1975	9.070
"	1976	12.345
"	1977	16.050
"	1978	20.920
"	1979	42.530
January	1980	43.890
June	"	52.315
January	1981	68.440
June	"	91.400
January	1982	132.440
June	"	173.190
January	1983	275.280
April	"	454.930

Note: As can be seen from these exchange rates, the rapid devaluation of the cruzeiro against the US dollar has been in progress for several years, and this makes analysis of dam costs etc. to be of little value.

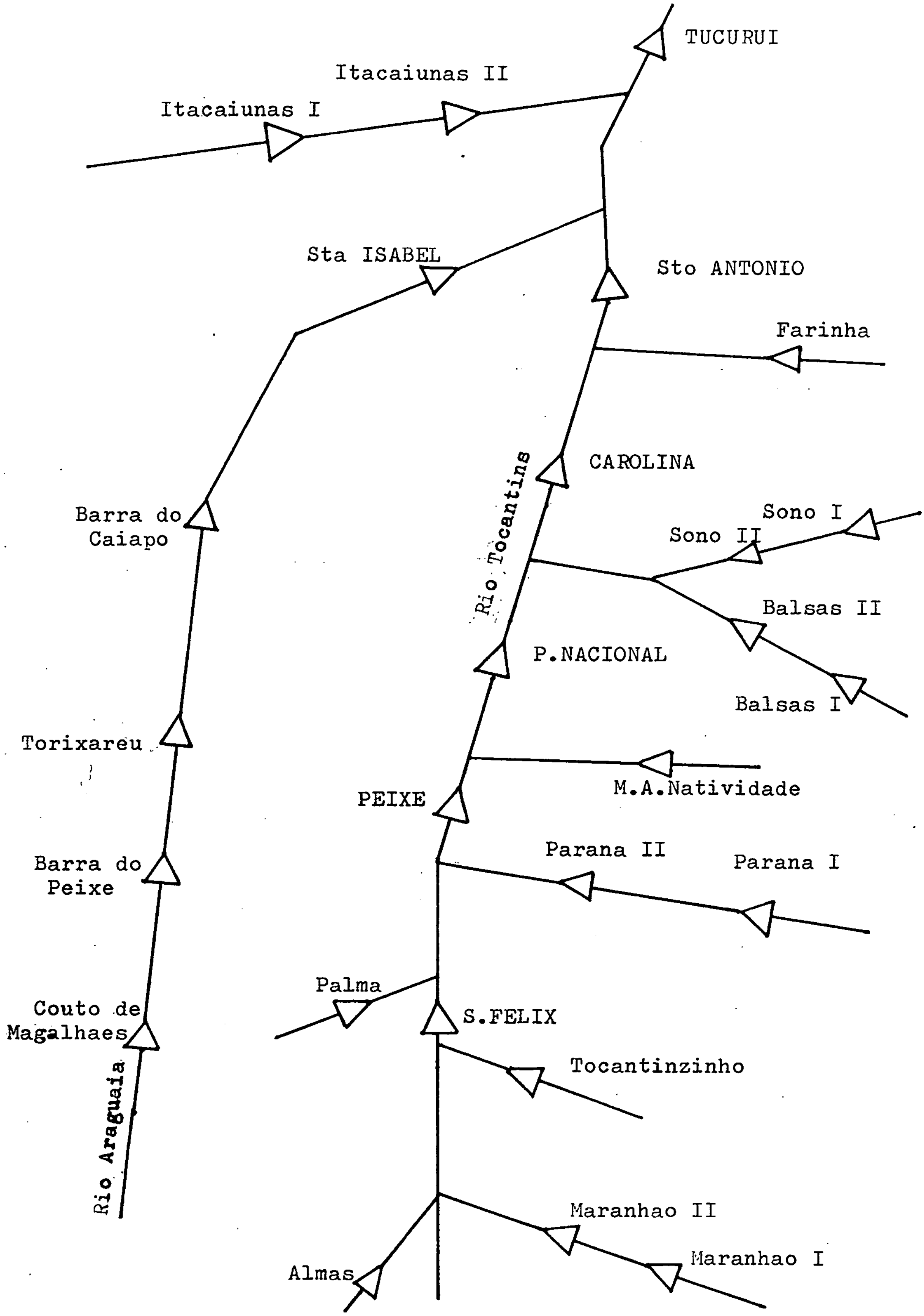
Source : Banco Central do Brasil, monthly report, April 1983.

Appendix 3 - ELETROBRAS Subsidiaries and Associated Companies

ELETRONORTE	Centrais Elétricas do Norte do Brasil S/A
ELETROSUL	Centrais Elétricas do Sul do Brasil S/A
FURNAS	Centrais Elétricas do Furnas S/A
CHESF	Companhia Hidro Elétrica do São Francisco
ESCELSA	Espirito Santo Centrais Elétricas
CEM	Companhia de Eletricidade do Manaus
CBEE	Companhia Brasileira de Energia Elétrica
CELETRAMAZON	Centrais Elétricas de Amazonas
CER	Centrais Elétricas de Roraima
ELETROACRE	Centrais Elétricas de Acre
CEA	Companhia de Eletricidade do Amapá
CELPA	Centrais Elétricas do Pará
CERON	Centrais Elétricas de Rondônia
CEMAR	Centrais Elétricas do Maranhão
CEPISA	Centrais Elétricas do Piaui
COELCE	Companhia de Eletricidade do Ceara
COSERN	Companhia de Serviços Elétricos do Rio Grande do Norte
SAELPA	Sociedade Anônima de Eletrificação da Paraiba
CELPE	Companhia de Eletricidade de Pernambuco
CEAL	Companhia de Eletricidade de Alagoas
ENERGIPE	Empresa Distribuiçao de Energia em Sergipe
COELBA	Companhia de Eletricidade do Estado da Bahia
COBER	Companhia Baiana de Eletrificação Rural
CESP	Centrais Elétricas de São Paulo
CPFL	Companhia Paulista de Força e Luz

CAIUA	Compahia Elétrica de Caiua
CLFSC	Companhia Luz e Força Santa Cruz
CELF	Centrais Elétricas Fluminenses
CENF	Companhia de Eletricidade de Novo Friburgo
EEVP	Empresa de Eletricidade Vale do Paranapanema
CFLCL	Companhia Força e Luz Cataguazes-Leopoldina
CME	Companhia Mineira de Eletricidade
CEMIG	Centrais Elétricas de Minas Gerais
ERMIG	Eletrificação Rural de Minas Gerais
LIGHT	Light Serviços de Eletricidade
COPEL	Companhia Paranaense de Energia Elétrica
CELESC	Centrais Elétricas de Santa Catarina
CEEE	Companhia Estadual de Energia Elétrica
CHEP	Companhia Hidro Elétrica de Paranapanema
CEMAT	Centrais Elétricas de Mato Grosso
CELG	Centrais Elétricas de Goias
CEB	Companhia de Eletricidade de Brasilia

Appendix 4 : Hydraulic Sites Inventoried in the Amazon Basin



Note : The dams of the Tocantins-Araguaia cascade are shown in capital letters.

Source : Departamento de Estudos Energeticos, ELETROBRAS, 1977.

Appendix 5 : UHE Tucurui - Technical Data

General

Drainage Area	758 000 km
Length of dam & concrete structure	4 885 m
Total volume of excavations	18 290 000 m^3
Total volume of infill material	39 344 000 m^3
Total volume of concrete	4 688 000 m^3
Total volume of cofferdam	7 302 000 m^3

Left Bank Dam

Type	Rockfill
Length	460.5 m
Max^m. Height	58 m

Left Bank Dike

Type	Earthfill
Length	774 m
Max^m. Height	71 m

Right Bank Dam

Type	Earthfill
Length	3 420 m
Max^m. Height	85 m

Right Bank Dike

Type	Earthfill
Length	5 850 m
Max^m. Height	20 m

River Flows

Average	9 208 m^3s^{-1}
Min^m. recorded	1 511 m^3s^{-1}
Max^m. recorded	63 00 m^3s^{-1}
River Diversion	51 000 m^3s^{-1}
Spillway Capacity	100 000 m^3s^{-1}

Heads

Max^m.	67.60 m
Min^m.	51.40 m
Nominal	60.80 m

Reservoir

NA Max^m.	74.00 m
NA Normal	72.00 m
NA Min^m.	58.00 m
Accumulated Volume	43×10^9 m^3
Usuable Volume	23×10^9 m^3
Area at NA Normal	2 160 km^2
Length	200 km

Spillway

Length	575 m
Max^m. Height	86 m
No. radial gates	23
Size	20×20 m^2

Powerhouse

Location	Semi-underground
Length	470 m
No. of units (1st stage)	12

Turbines

Type	Francis
Number	12
Max^m. Capacity	330 MW
Capacity under nominal head	316 MW
Capacity under min^m. head	250 MW
Speed	83.72 rpm
Discharge under nominal head	576 m^3s^{-1}

Generators

Nominal Capacity (continuous)	350 MVA
Frequency	60 Hz
Nominal Voltage	13.8 kV
Speed	83.72 rpm
Power Factor	0.95

Transformers

Number	9
Nominal Capacity	350 MVA
Voltage	13.8/500 kV

Bibliography

1. Tendler J. "Electric Power in Brazil : Entrepreneurship in the Public Sector", Harvard University Press, Cambridge, Mass., 1968, pp.264.

2 - 16 papers prepared by the Brazilian Embassy, London, 1975-77

2. No.1 Brazil - A Continent in Expansion.

3. No.2 Brazilian Development - The Role of the Church and State.

4. No.3 The Brazilian Development Model - An Experiment in Growth.

5. No.4 'Monetary Correction', A Brazilian Experience.

6. No.5 Social Aspects of Brazilian Economic Development.

7. No.6 Brazil's Foreign Policy (I).

8. No.7 Brazil on the March (I).

9. No.8 Brazil's Foreign Policy (II).

10. No.9 Brazil's Foreign Policy (III).

11. No.10 Amazonia, 1976, pp.32.

12. No.11 Agriculture, Mining and Oil in Brazil (I) - Key Sectors of the Brazilian Economy, No.1, 1976, pp.38.

13. No.12 Transport and Telecommunications in Brazil No.2, 1976, pp.27.

14. No.13 Brazil on the March (II), 1976, pp.89.

15. No.14 Brazil - A Geography, 1977, pp.63.

16. No.15 Brazil's Energy and Heavy Industries, 1977, pp.44.

17. Dickenson J.P. "Brazil", Dawson, England, and Westview, Colorado, 1978, pp.246.

18. Momsen R.P. "Brazil - A Giant Stirs", Van Nostrnad, London, 1968.

19. Flynn P. "Brazil - A Political Analysis", Ernest Benn, 1978, pp.592.

20 - 24 Financial Times Surveys, published by Financial Times Limited, London.

20. "Brazil", 7 December 1978.

21. "Brazil Banking and Insurance", 18 July 1979.

22. "Brazil", 16 October 1979.

23. "Brazil", 14 November 1980.

24. "Brazil", 18 November 1981.

25 - 26 Times Special Supplements, published by Times Newspapers Limited, London.

25. "Banking and Finance in Latin America", 8 November 1978.

26. "Brazil", 23 July 1980.

27. Journal do Brasil, published by Journal do Brasil Limitida, Rio de Janeiro.

28. Folho de São Paulo, published by Empresa da Folha da Manhã S.A., Sao Paulo.

29. O Globo, published by Fundação de Irineu Marinho, Rio de Janeiro.

30. Fundação Instituto do Geografia e Estatística "Annuario Estatístico do Brasil", Diretoria de Divulgação, Centro Editora 1, Rio de Janeiro.

31. Yearbook of National Accounts Statistics 1979, Vol. II, International Tables, United Nations, New York, 1980.

32. Furtado C. "Development and Underdevelopment", translated by Aguiar R.W. and Drysdale E.C., University of California Press, 1964, pp.181.

33. Furtado C. "Economic Development in Latin America", translated by Macedo S., Cambridge University Press, 1970, pp.271.

34. Federal Government of Brazil "O Plano Nacional de Desenvolvimento - O Primeiro (1972 - 1974), Brasilia, 1972, pp.76.

35. Op cit note 34, "O Segundo (1975 - 1979)", Brasilia, 1974, pp.152.

36. Op cit note 34, "O Terceiro (1980 - 1985)", Brasilia, 1981, pp.160.

37. CIIR "São Paulo Growth and Poverty" - a report from the São Paulo Justice and Peace Commission, the Bowerdean Press in association with the Catholic Institute for International Relations, 1978, pp.128.

38. Hall A. "Irrigation in the Brazilian North-East : Anti-drought or Anti-peasant, undated, pp.22.

39. Anon "Terceiro Mundo tem no Brasil um exemplo de Desenvolvimento, Commercio e Mercados, Ano VII, no.72, August 1973, pp.24-25.

40. Tyler W.G. "The Brazilian Industrial Economy", Lexington Books, Massachusetts, 1981, pp.152.

41. Kahil R. "Inflation and Economic Development in Brazil, 1946-1963", Clarendon Press, Oxford, 1973, pp.537.

42. Commercio e Mercados - orgão da Confederação Nacional do Commercio, published by the Divisão de Relacões Publicas e Divulgação da CNC, Rio de Janeiro.

43. Planejamento e Desenvolvimento, published by the Orgão da Coordenação de Relações Publicas da Secretaria de Planejamento da Presidencia da Republica, Rio de Janeiro.

44. Anon "Uma balanco positivo e uma perspectiva otimista", Mundo Eletrico, Ano 19, n.220, January 1978, p.11.

45. Op cit note 34.

46. Op cit note 35.

47. Op cit note 36.

48. Anon "Ilha Solteira : um marco do progresso", Energia Eletrica no.12, March 1979, p.4.

49. Cotta P. "Inflação no Brasil e a OPEP de 1980", Minas e Energia, Ano 1, no.2, February 1980, p.50-51.

50. Yang V., Trinidade S.C. "Brazil's Gasohol Programme", Chemical Engineering Progress, April 1979, p.11-19.

51. Op cit note 16, p.17.

52. Personal communication.

53. Mundo Eletrico, published by Max Gruenwald e Companhia Limitida, Sao Paulo.

54. Revista Construção Pesada, published by Novo Grupo - Editora Tecnica Limitida, Sao Paulo.

55. Revista Brasileiro de Energia Elétrica, published by ELETROBRAS, Rio de Janeiro, 1963 -.

56. Relatorio Reservado, publisher unknown, published in Rio de Janeiro.

57. Revista do Clube de Engenharia, published by the Clube de Engenharia, Rio de Janeiro.

58. Energia Elétrica, published by Novo Grupo - Editora Tecnica Limitida, Sao Paulo.

59. Canambra Engineering Consultants Limited "Power Study of South Central Brazil, Part B, Sao Paulo Group", 1966.

60. Canambra Engineering Consultants Limited "Power Study of South Brazil, Comprehensive Report", 1969.

61. ELETROBRAS "Plano 90 - Plano de Atendimento dos Requisitos de Energia Elétrica ate 1990, Regioes Sudeste e Sul", 1974.

62. MME, ELETROBRAS "Plano de Atendimento dos Requisitos de Energia Elétrica ate 1995" (Plano 95), 1979.

63. ELETRONORTE "Tucurui Hydroelectric Project - Summary", English version supplied by ELETRONORTE, undated, pp.17.

64. GCOI Sudeste/Sul, Subcomite de Estudos Energeticos "Plano de Operação para 1980", Vol. 1-3, ELETROBRAS, 1979, pp.329.

65. Anon "Setenta e cinco anos de energia elétrica no Brasil", Mundo Eletrico, Ano 18, no.207A, December 1976, pp.168.

66. Anon "A Energia Eletrica no Brasil", Biblioteca do Exercito Editora, Rio de Janeiro, publication no.474, 1977, pp.244.

67. Op cit note 1.

68. Water Power and Dam Costruction, published by Business Press International, England.

69. Journal of the Institution of Electrical Engineers, published by the IEE, London.

70. Journal of the Institute of Civil Engineers, published by ICE, London.

71. Ackerman W.C., White G.F., Worthington E.B.(eds) "Man-Made Lakes : Their Problems and Environmental Effects", Geophys. Mono. Ser. Vol. 17, A.G.U., Washington D.C., 1973.

72. Anon "Furnas e sua area de influencia", Mundo Eletrico, Ano 16, no.190, July 1975, p.10-13.

73. Caulfield C. "The Last of the Nambiquara", New Scientist, Vol. 87, no.1213, 7 August 1980, p.460-462.

74. Scudder T. "Man-Made Lakes and Population and Resettlement in Africa" from Lowe-McConnell R.H. (ed) "Man-Made Lakes", Institute of Biology, 1966, p.99-108.

75. Black P.E. "Impact of Traditional Water Resources Technology on the Human Environment", 1st World Congress on Water Resources, Chicago, 1973, p.253-263.

76. Op cit note 71, Glymph C.M. "Sedimentation of Reservoirs", p.342-348.

77. Goodland R.J.A. "Environmental Optimisation in Hydro-development of Tropical Forest Regions" from "Man-Made Lakes and Human Health", Proc. of Symp. on Man-Made Lakes and Human Health, University of Suriname, Paramaibo, Suriname, 1977, (reprint).

78. Utton A.E., Teclaff L. (eds) "Water in a Developing World - The Management of a Critical Resource", Westview Press, Colorado, pp.279.

79. MacGregor A.N., Keeney D.R. "Nutrient Reactions" from Stanley N.F., Alpers M.P. (eds) "Man-Made Lakes and Human Health", Academic Press, London, 1975, p.238.

80. Imevbore A.M.A. "The Kainji Dam and Health" from "Man-Made Lakes and Human Health" op cit note 79, p.218.

81. Hughes C.C., Hunter J.M. "The Role of Technological Development in Promoting Disease in Africa" from Farvar M.T., Milton J.P. (eds) "The Careless Technology", The Natural History Press, New York, 1968, p.69-84.

82. Michel A.A. "The Impact of Modern Irrigation Technology in the Indus and Helmland Basins of South West Asia" from "The Careless Technology" op cit note 81.

83. Biswas A.K., Biswas M.R. "Environmental Consequences of Increasing World Food Production", Department of the Environment, Ottawa, 1975.

84. Souto Silveira E.B., Pinca R.L., Eigeneer L.P.Q.T. "Flood Control in the Taiaçupeba Basin", Water Power and Dam Construction, 1976, 28(4), p.64-66.

85. Anon "Large dams blamed for Brazilian floods" Water Power and Dam Construction, 1980, 32(4), p.3.

86. Rothe J.P. "Fill a lake, start an earthquake", New Scientist 1968, Vol.39, no.605, p.75-78.

87. El-Shamy F.M. "Environmental Impacts of Hydroelectric Power Plants", Proc. ASCE (HY9), 1977, 103(2), p.1007-1019.

88. Little E.C.S. "Aquatic Plants" from "Man-Made Lakes and Human Health" op cit note 79.

89. Walsh J., Gannon R. "Time is short and the water rises", Nelson, London, 1967.

90. Op cit note 83, p.33.

91. El-Zarka S.E. "Effects of the Construction of the Aswan High Dam on the Sardine Fishery of the UAR Waters of the Mediterranean Sea", Int. Symp. on Man-made Lakes, National Academy of Sciences, T.V.A., University of Tennessee, 1971.

92. Op cit note 16, p.6.

93. Agarwal A.K. "Crippling cost of India's big dam", New Scientist, 1974, Vol.65, no.934, p.260-261.

94. Personal observation, 1980.

95. Anon "Sobradinho dam inaugurated", Water Power and Dam Construction, 1978, 30(8), p.7.

96. Anon "Manifesto sobre barragens no Alto Uruguai", Journal de Santa Catarina 28 March 1980.

97. Martins J.de S. "Fighting for the Land : Indians and Posseiros in Legal Amazonia" from "Land, People and Planning in Contemporary Amazonia", Proc. of Conf. on Development of Amazonia in Seven Countries, Cambridge, England, ed. F. Barbira-Scazzocchio, 1979, p.97.

98. Interview with FURNAS personnel

99. Anon "Itaipu", Construçao Pesada, March 1979, p.11-17.

100. ELETRONORTE "Usina Hidreletrica de Tucurui - Projeto Basico", 1976, p.84-88.

101. Op cit note 99.

102. Op cit note 100.

103. Moraes M., Dias L.B. "Oncocercose no estado de Amazonas, Brasil", Rev. Inst. Med. Trop. Sao Paulo, 1972, 14(5), p.330-333.

104. Anon "Plague", The New Encyclopaedia Britannica, Micropaedia Vol.VIII, 1982, p.20.

105. Anon "Chagas' Disease", The New Encyclopaedia Britannica, Micropaedia Vol.II, 1982, p.707.

106. Personal communication

107. CESP "Brazilian Dam Failures : a preliminary report", Water Power and Dam Construction, 1977, 29(10), p.51-53.

108. Anon "Lardge Dams blamed for Brazilian Floods", Water Power and Dam Construction, 1980, 32(4), p.3.

109. Goodland R.J.A. "Itumbiara Hydroelectric Project - Environmental Impact Reconnaissance", The Cary Arboretum, New York, 1972, pp.89.

110. Goodland R.J.A. "Salto Santiago Hydroelectric Project and Transmission System", The Cary Arboretum, New York, 1975, pp.124.

111. Goodland R.J.A. "Sobradinho Hydroelectric Project - Environmental Impact Reconnaissance", The Cary Arboretum, New York, 1973, pp.105.

112. Filho C.de O., Paiva M.P. "Indicações de Usos Multiplos das Principais Represas Hidrelétricas do Brasil", ELETROBRAS Rio de Janeiro, January 1977, pp.20.

113. Bard J., de Oliveira L.P.H., Paiva M.P. "Plano de Peixamento da Represa de Furnas (Rio Grande), ELETROBRAS, Rio de Janeiro, November 1978, pp.23.

114. Menezes L.C., Pereira A.de A. "O Seto Eletrico e o Meio Ambiente", ELETROBRAS, Rio de Janeiro, March 1979, pp.59.

115. Moreira M.de M., da Silva L.M., McLaughlin R. "Country Profiles - Brazil", The Population Council, Inc., New York, May 1978, pp.24.

116. DEME "Referencias Econômicas para o Planejamento", ELETROBRAS Rio de Janeiro, June 1979, p.3.2-3.3.

117. Op cit note 115, p.3-10.

118. Ibid, p.6.

119. Henshall J.D., Momsen R.P. Jnr. "A Geography of Brazilian Development", G. Bell & Sons Limited, London 1976, p.238.

120. Op cit note 15.

121. Ibid, p.5-8.

122. Report in the "Latin American Daily Post", Rio de Janeiro, December 1979.

123. O'Shaughnessy H. "Brazil : a miracle no more", Financial Times, 26 March 1979.

124. Kucinski B. "Another general will be Brazilian President", The Guardian, London, 15 March 1979.

125. Turner R. "Attitudes hardening in Sao Paulo strike", Financial Times, London, 21 March 1979.

126. Op cit note 12, p.32.

127. Ibid.

128. Op cit note 16, p.15.

129. Ibid, p.6.

130. Op cit note 14, p20-24.

131. Op cit note 50.

132. de Carvalho Jnr. A.V., Rechtschaffen E.E.M., Saddy M., "Future Scenarios of Alcohols as Fuels in Brazil", paper presented at the Alcohol Fuels Technology, 3rd Int. Symp, Asilomar, California, 28-31 May 1979, Vol III.

133. Op cit note 12.

134. Anon "Recursos Naturais", Editora Gondwana, undated.

135. Op cit note 35.

136. Interview with Senior FURNAS official,

137. Anon "Itaipu Project still on Schedule", Financial Times, London, 7 December 1978.

138. Op cit note 15.

139. Op cit note 35, p.82.

140. MME "Balanco Energetico Nacional" Ministerio de Minas e Energia, Brasilia D.F., 1978.

141. Goldemberg J. "Brazil : Energy Options and Current Outlook", Science, Vol.200, 14 April 1978, p.158-164.

142. Ibid p.158.

143. Ibid p.159.

144. ELETROBRAS "Recursos Energéticos para a Expansão dos Sistemas", ELETROBRAS, October 1979, pp.198.

145. Op cit note 22, p.VI.

146. Op cit note 13, p.7-10.

147. Phillips T.P., Milfont Jnr. W.N. "Assessment of Agricultural Energy Production Systems - AEPS", paper presented at the

"Caribbean Consultation on Energy and Agriculture", Santo Domingo, Dominican Republic, 29 November - 1 December 1978, on behalf of Centro de Tecnologia, Promon, Rio de Janeiro.

148. CTP "World's first commercial plant starts operation in Brazil", Centro de Tecnologia Promon Newsletter, Vol.3(1), February 1978, p.1.

149. Op cit note 132.

150. Op cit note 50.

151. Trindade S.C., Albuquerque C. "O balanço energetico brasileiro", Congresso Brasileiro de Petroquimica 1, Rio de Janeiro, 8-12 November 1976, p.15-22.

152. Williams V.C. "Averting the crisis", Water Power and Dam Construction 1980, 32(12), p.21.

153. Op cit note 23.

154. Op cit note 49.

155. Anon "Energia : o desafio e as respostas", Commercio e Mercados, Ano XIII, no.141, May 1979, p.2.

156. Ibid.

157. Op cit note 155, p.5.

158. Op cit note 16, p.15.

159. Op cit note 61, p.IV-23.

160. Op cit note 62, p. 2.7, table 2.1.

161. Op cit note 61, p.IV-22.

162. Personal communication.

163. Keesings Contemporary Archives, London, 1977, item no.28195.

164. Op cit note 16, p.17.

165. Cotrin J.R. "A Primeira Central Nuclear", Revista Brasileira de Energia Eletrica, no.11, April-October 1969, p.17-20.

166. Bazin M. "The politics of power in Brazil", Science, Vol. Vol.284, 24 April 1980, p.655-657.

167. Anon "Mais energia e novas mercados", Comercio e Mercados, Ano VII, no.70, January 1973, p.34-37.

168. Op cit note 166.

169. Op cit note 160.

170. Leite Jnr. A.D. "Perspectivas da Energia no Brasil", Revista Brasileira de Energia Eletrica, no.26, October-December 1973, p.46-49.

171. Op cit note 167.

172. Anon "Crise energetica e ume questão econômica", Mundo Eletrico Ano 15 , no.168 , September 1973, p.8-11.

173. Keesings Contemporary Archives, London, 1978, item no. 28762A.

174. Op cit note 166, p.655.

175. Op cit note 169.

176. Op cit note 166, p.657.

177. Op cit note 169.

178. Smith D. "Brazil stands by nuclear deal", Financial Times, London, 6 April 1979.

179. Smith D. "Nuclear deal runs up against Brazil's new freedoms" Financial Times, London, 19 April 1979.

180. Gomes W. "As opções do Pais diante da crise", Minas e Energia Ano 1, no.1, November 1979, p.11-14.

181. Anon "Developing countries fall further behind", Water Power and Dam Construction, 1980, 32(11), p.5.

182. Schulman M. "Potencial hidrelétrica do Brasil", Energia Eletrica, no.20, November 1979, p.64-75.

183. James P.E. "Water Power Resources in Brazil", Economic

Geography, 1942, Vol. XVIII, p.13-16.

184. Op cit note 59.

185. Op cit note 60.

186. Op cit note 182.

187. Jeffs E. "Energy Profile of Brazil", Energy International 1976, 13(9), p.21.

188. Canambra Engineering Consultants Limited "Power Study of South Brazil" - Appendix IX "The Uruguai River Basin, November 1968.

189. Op cit note 62, p.5.1.

190. Op cit note 95.

191. Filho W.J. "Desenvolvimento do potencial hidréletrico brasileiro", Construcao Pesada, Ano 9, no.110, March 1980, p.128

192. Op cit note 182.

193. ELETRONORTE "Relatorio de Atividades 1978", MME, 1979, p.7

194. Op cit 191.

195. Carliani R.M., Filho W.J. "Pumped Storage Development in Brazil", Part I, Water Power and Dam Construction, 1981, 33(1), p.60-65.

196. Ibid, Part II, Vol.33(2), p.41-44.

197. Ibid, Part III, Vol.33(3), p.40-42.

198. Dutra B. "A nova fisionomia do setor de energia eletrica", Revista Brasileira de Energia Elétrica, no.8, April - December 1965, p.2-3.

199. ELETROBRAS "ELETROBRAS 1978 Report", English version, 1978 pp.36.

200. Ibid

201. Op cit note 62, p.2.1.

202. Op cit note 61, table 6.5.

203. Op cit note 123.

204. Smith D. "Brazil curbs state imports", Financial Times, London, 24 January 1979.

205. Anon "Expansão do mercado reclama maiores investimentos", Mundo Eletrico, Ano 21, no.246, March 1980, p.22-25.

206. de Salvo Brito S. "Electrical Supply Systems and National Development - The Brazilian Experience", paper delivered at Cigre International Conference on Large High Voltage Electric Systems, Paris, September 1978.

207. de Franco N., Morrissey C.A.S. "An account of long term transmission system development in Brazil", paper prepared for conference presentation, 1979, pp.10.

208. Op cit note 116.

209. Op cit note 62, p.2.

210. Anon "Balanco energetico preve a redução de fontes importadas", Mundo Eletrico, Ano 19, no.228, September 1978, p.18-20.

211. Op cit note 199, p.9.

212. United Nations "Yearbook of National Accounts Statistics", 1979, Vol.II, International tables, p.101.

213. World Bank "World Tables - 2nd edition 1980", published for the World Bank by John Hopkins University Press, Baltimore and London, 1980, p.48-49.

214. Op cit note 116.

215. Anon "Registro Geral de Grandes Barragens Brasileiras", Construção Pesada, Ano 6, no.61, February 1976, p. 20-53.

216. Op cit note 61, p.IV-6.

217. Op cit note 62, p.10.

218. Op cit note 66, p.69.

219. Op cit note 1, p.47-48.

220. Op cit note 66, p. 70-72.

221. de Aguiar M.P. "A importancia da participação do capital nacional na expansão do parque energético", Revista Brasileira de Energia Eletrica, no.4, January-February 1964 p.2.

222. Op cit note 66, p.89-90.

223. Op cit note 221.

224. Anon "ELETROBRAS muda a sistema de suas obrigações", Revista Brasileira de Energia Eletrica, no.34, April-September 1976, p.55.

225. Anon "Realizações mas tambem problemas", Mundo Eletrico, Ano 10, no.114, March 1969, p.7.

226. de Menezes S.C. "Financiamento conjunto : uma nova experienca para o Brasil", Revista Brasileira de Energia Eletrica, no.18, October- December 1971, p.12-16.

227. Anon "As atuais dimensões do credito internacional", Mundo Eletrico, Ano 13, no.152, May 1972, p.8-9.

228. Anon "Credito de confianca", Revista Brasileira de Energia Eletrica, no.28, April-June 1974, p.2.

229. Interview with senior ELETROBRAS personnel, December 1979.

230. Anon "Latin-American power loans", Water Power and Dam Construction, 1976, 28(8), p.9.

231. Op cit note 199.

232. Anon "ELETROBRAS seeks $400m loan", Financial Times,

London, 24 January 1979.

233. Smith D. "Brazilian deficit soars", Fincial Time, London, 14 February 1979.

234. Evans J. "Brazil's ELETROBRAS achieves better terms for $400m loan", Financial Times, London, 19 February 1979.

235. Anon "ELETROBRAS financing", Financial Times, London, 28 March 1979.

236. Smith D. "Brazilian's limit foreign borrowing", Financial Times, London, 30 March 1979.

237. Dullforce W. "ASEA wins $900m Brazilian contract", Financial Times, London, 4 May 1979.

238. Ibid.

239. Op cit note 359

240. Op cit note 656

241. Op cit note 66, p.15.

242. Op cit note 199, p.5.

243. Op cit note 65, p.12.

244. Op cit note 66, p.53.

245. Electricity Council "Electricity supply in Great Britain - A Chronology", The Electricity Council, London, 1973, p.4.

246. Ibid, p.3.

247. Op cit note 65, p.14.

248. Anon "Hidrelétrica de Juiz de Fora na America Latina", Revista Brasileira de Energia Elétrica, no.1, August 1963, p.4-11.

249. Op cit note 66, p.54.

250. Ibid, p.55.

251. Ibid.

252. Sharlin H.I. "The Making of the Electrical Age", Abelard-Schuman, 1963, p.153.

253. Ibid, p.167-168.

254. Op cit note 65, p.16.

255. Op cit note 66, p.56.

256. Op cit note 252, p.179.

257. Op cit note 1, p.7.

258. Op cit note 66, p.57.

259. Billing's A.W.K. "Water Power in Brazil", The Engineering Journal, August 1930, p.493-503.

260. Op cit note 1, p.7-8.

261. Ibid, p.9.

262. Op cit note 259, p.493.

263. Op cit note 1, p.8.

264. Op cit note 66, p.97.

265. Op cit note 65, p.16.

266. Op cit note 66, p.57.

267. Op cit note 65, p.20.

268. Op cit note 66, p.57.

269. Op cit note 65, p.20.

270. Ibid.

271. Op cit note 66, p.57.

272. Op cit note 65, p.20.

273. Op cit note 259, p.498.

274. Op cit note 65, p.20-21.

275. Anon "Registro Geral de Grandes Barragens Brasileiras", Construção Pesada, Ano 6, no.61, February 1976, p.20-53.

276. Op cit note 1, p.31.

277. Op cit note 65, p.22.

278. Op cit note 259, p.494.

279. Op cit note 15, p.12.

280. Couzens R.W.H. "The Serra Hydroelectric Development, Sao Paulo, Brazil", J. Inst. Elec. Eng., 1930, Vol. 68, p.1291-1300.

281. Op cit note 259, p.494.

282. Op cit note 1, p.31.

283. Op cit note 280. p.1300.

284. Op cit note 259, p.500.

285. Billings A.W.K. "Water Power in Brazil, with Special Reference to the Saõ Paulo Development", J. Inst. Civ. Eng., 1936, 3(8), p.677-698.

286. Ibid, p.685.

287. Op cit note 65, p.24.

288. Op cit note 285, p.687.

289. Ibid, p.697.

290. Op cit note 259, p.502.

291. McCullough D. "The Path between the Seas - The Creation of the Panama Canal 1870-1914", Simon & Schuster, 1977.

292. Op cit note 65, p.24.

293. Op cit note 259, p.502.

294. Op cit note 285, p.698.

295. Op cit note 275, p.27-29.

296. Op cit note 285, p.691.

297. Anon "Symposium on Water Hammer", American Soc. Mech. Eng. & American Soc. Civ. Eng., 1933.

298. Op cit note 285, p.691.

299. Ibid, p.690.

300. Op cit note 65, p.58.

301. Op cit note 1, p.33.

302. Op cit note 65, p.24.

303. Ibid, p.26.

304. Op cit note 66, p.58.

305. Op cit note 65, p.26.

306. Water Power and Dam Construction 1953 August, p.289.
'The Paraiba - Pirai Diversion, Anon. p.287-293

307. Op cit note 65, p.30.

308. Anon "Três Marias Dam", part II, Water Power and Dam Construction, 1960, 12(1), p.63.

309. Burton Sir R.F. "Explorations of the Highlands of Brazil" ed. I. Burton, Tinsley Bros., London, 1869.

310. Op cit note 65, p.50.

311. Op cit note 66, p.74.

312. Op cit note 65, p.50-54.

313. Ibid, p.30.

314. FURNAS "FURNAS - organização e atividades", FURNAS, Rio de Janeiro, undated, pp.22.

315. Op cit note 1, p. 7-23

316. Ibid, p.37.

317. Op cit note 66, p.75.

318. Anon "Furnas e sua area de influencia", Mundo Eletrico, Ano 16, no.190, July 1975, p.10-13.

319. Op cit note 65, p.30.

320. Cotrim J.R. "The Furnas Hydro-Electric Development", Water Power and Dam Construction, 1958, 10(11), p.425-429.

321. Op cit note 65, p.30.

322. FURNAS Public Relations Document, 1977, pp.24.

323. Op cit note 1. p. 37

324. Op cit note 136.

325. Ibid.

326. Anon "Três Marias Dam", part I, Water Power and Dam Construction, 1959, 11(12), p.446-447.

327. Anon "Três Marias Dam", part III, Water Power and Dam Construction, 1960, 12(2), p.63.

328. Op cit note 188.

329. ELETROSUL, CNEC "Bacia Hidrografica do rio Uruguai - Estudo de Inventario Hidroenergético", Vol.1 Relatorio Geral, October 1979.

330. Ibid, p.G3-G16.

331. Boletim dos Trabalhadores Rurais atingidos pela Barragem de Itaparica, no.1, August 1979, Bahia.

332. Op cit note 96.

333. Op cit note 38.

334. Op cit note 96.

335. Op cit note 329, p.IU2.

336. Anon "Itaipu", public relations document published by Sinforma, Rio de Janeiro, undated, pp.56.

337. Anon "Paraguay - Power Game", Latin American Bureau (Research and Action) Limited, 1980, pp.76.

338. Anon "Brazil backs out of Itaipu accord", Water Power and Dam Construction, 1979, 31(4), p.3.

339. Anon "Itaipu", Revista Brasileira de Energia Eletrica, no.24, April-June 1973, p.46-57.

340. Anon "Itaipu : escala da obra e cronograma apertado forjaram os maiores problemas e forcaram as solucões", Construcao Pesada, Ano 7, no.82, November 1977, p.59-180.

341. Anon "Itaipu : a conquista dos maiores indices de des desenvolvimento tecnologico ja alcançados pelo homen", Construção Pesada, Ano 9, no.98, March 1979, pp.174.

342. Anon "Itaipu atinge pico de concretagem de 15 000 m^3 diarios", Construção Pesada, Ano 9, no.110, March 1980, p.56-62.

343. Special edition on Itaipu Energia Elétrica, Ano 2, no.18, September 1979, pp.62.

344. Op cit note 336, p.1.

345. Anon "Itaipu", Revista Brasileira de Energia Elétrica, no.24, 1973, p.46.

346. Anon "50% da energia de Itaipu para São Paulo", Mundo Eletrico, Ano , no.170, November 1973, p.48.

347. Op cit note 160.

348. Op cit note 64.

349. Op cit note 336.

350. Anon "Itaipu Binacional", public relations booklet, published by Itaipu Binacional, undated, pp.28.

351. Anon "1979 - ano decisivo na construção das obras civis de Itaipu", Construção Pesada, no.110, March 1980, p.24.

352. Anon "Desvio do rio marca etapa decisiva de Itaipu", Mundo Eletrico, Ano 20, no.229, October 1978, p.20-29.

353. Anon "Keeping cool at Itaipu", Water Power and Dam Construction, 1979, 31(6), p.64-66.

354. Anon "Os problemas de Itaipu na politica, econômia, engenharia", Mundo Eletrico, Ano 19, no.214, July 1977, p.10

355. de Moraes J., Rodriguez J., Gummer J.H., del Brenna F. "Turbines for Itaipu", Water Power and Dam Construction, 1981, 33(12), p.34-41.

356. Information memorandum on Itaipu Binacional of 3 April 1978, given to potential financers of a US$175m medium term loan.

357. Op cit note 346.

358. Itaipu Binacional "Relatorio Anual 1978", Itaipu Binacional, 1978

359. Ibid.

360. Anon "Itaipu : prioridade ou racionamento", Mundo Eletrico Ano 19, no.215, August 1977, p.11.

361. O'Shaughnessy H. "A first taste of wild inflation", Financial Times, London, 12 October 1979.

362. Op cit note 337, p.48.

363. Leitão M. "Paraguai reve precos de Itaipu", Gazeta Mercantil, São Paulo, 9 April 1980.

364. Op cit note 337, p.48.

365. Op cit note 358, p.63.

366. Nickson A. "Brazilian colonization of the eastern border region of Paraguay", from "Land, People and Planning in Contemporary Amazonia" op cit note 97, p.173.

367. Anon "Acordo tripartite permite flexibilidade operacional" Mundo Eletrico, Ano 21, no.242, p.42.

368. Personal communication.

369. Feijo A. "Sete Quedas - antes do diluvio", Manchete, undated.

370. Op cit note 62.

476. CESP "O Tiete navegavel : concretizacao um sonho de 40 anos", CESP public relations document, São Paulo, undated.

477. Anon "Double disaster for Brazilian earthfill dams", Water Power and Dam Construction, 1977, 29(3), p.3.

478. Interview with personnel from Departamento de Operação Energetico, ELETROBRAS, Rio de Janeiro, April 1980.

479. Op cit note 199, p.36.

480. Op cit note 478.

481. Interview with senior personnel Departamento de Estados de Mercado, ELETROBRAS, April 1980.

482. Op cit note 116.

483. Op cit note 442.

484. Op cit note 65, p.89.

485. Op cit note 59, p.3.

486. Op cit note 1, p.41.

487. Op cit note 60, p.336.

488. Op cit note 59, p.8.

489. Op cit note 59.

490. Op cit note 60.

491. Ibid, Appendix III.

492. Op cit note 59, p.15.

493. Op cit note 60, Introduction.

494. Ibid, p.336-338.

495. Op cit note 346.

496. Op cit note 59, p.24.

497. Op cit note 60, Summary p.7.

498. Ibid, p.30.

499. Ibid, p.10.

500. Op cit note 59, p.1-3.

501. Op cit note 60, p.XIV-3.

502. Ibid, p.IXV-5.

503. Op cit note 59, Appendix XII.

504. Op cit note 60, p.9.

505. Op cit note 59, p.1.3-1.6.

506. Op cit note 497, p.7.

507. Op cit note 59, p.1.8-1.9.

508. Ibid, p.1.10.

509. Op cit note 497, p.7.

510. Op cit note 59, p.xvii-xviii.

511. Ibid, p.xiv.

512. ELETROBRAS "Metodologia para o planejamento da expansão do sistema eletrica Brasileira", Diretoria de Planejamento e Engenharia, ELETROBRAS, Rio de Janeiro, October 1978.

513. Ibid, p.1-2.

514. Subcomite de Estudos Energeticos "Plano de Operação para 1980", GCOI Sudeste/Sul, Rio de Janeiro, September 1979, Vol.1, p.14.

515. Op cit note 141.

516. Op cit note 514, p.3.

517. Op cit note 144.

518. Ibid.

519. Op cit note 116, p.21.

520. Interview with Senior Personnel DEME, 1980.

521. Op cit note 116.

522. Anon "O planejamento no setor de energia eletrica", Mundo

Eletrico, Ano 16, no.189, June 1975, p.14-16.

523. Subcomitê de Estudos Energeticos, Grupo de Trabalho de Estudos Energeticos "Programa de Operação, 1° Trimestre de 1980", GCOI Sul/Sudeste, Rio de Janeiro, January 1980, p.2.

524. Colo A., Carvalho M.A.P., Pimental R.F. "Metodologia para planejamento da expansão do parque gerador do sistema eletrica Brasileira", Anais do CBE, December 1978.

525. Carvalho M.A.P., Pimental R.F. "Sistema de Planejamento da Expansão do Parque Gerador de Energia Eletrica Brasileiro", ELETROBRAS, 1978.

526. Personal Communication.

527. Op cit note 525.

528. Sioli H. preface to Goodland R.J.A., Irwin H.S. "Amazon Jungle : Green Hell to Red Desert?", Elsevier, 1975.

529. Goodland R.J.A., Irwin H.S. "Amazon Jungle : Green Hell to Red Desert?", Elesevier, 1975, p.2.

530. Op cit note 11, p.3-4.

531. Von Martius K.F.P. et al "Flora Brasiliensis", Berlin, 1829-1906, 40 vols.

532. Bates H.W. "The Naturalist on the River Amazons", Everyman, London, 1863.

533. Spruce R. "Notes of a Botanist on the Amazon and Andes during the years 1849-1864", MacMillan, London, 1908, 2 vols.

534. Wallace A.R. "Narrative of Travels on the Amazon and the Rio Negro", Reeve and Company, London, 1905.

535. Op cit note 11.

536. Op cit note 97, p.80-93.

537. Op cit note 529, p. 110

538. Op cit note 529, p.64.

539. Brooks E, Fuerst R., Hemming J., Huxley F. "tribes of the Amazon Basin in Brazil 1972", Report for the Aborigines Protection Society, Charles Knight and Co. Ltd., London, 1973, p.19.

540. Op cit note 529, p.64.

541. Personal Communication.

542. Op cit note 11, p.7.

543. Davis S. "Mining Projects endanger the Amazon's Yanomamo tribe", Multinational Monitor, Vol.1, February 1980, p.20-26

544. Lewis N. "The Rape of Amazonia", Observer, 22 April 1979.

545. Johnson P. "Fighting the Frontier Fever", Ceres, July-August 1978, p.23-30.

546. Op cit note 541.

547. Cottrill A. "Trans-Amazon Highway - the last great construction adventure", New Civil Engineer, 16 August 1973, p. 5-11.

548. Op cit note 529, p.65.

549. Op cit note 539, p.201.

550. Moran E.F. "Mobility and Resource Use in Amazonia" from "Land, People and Planning in Contemporary Amazonia, op cit note 97, p.46-47.

551. O'Shaughnessy H., Corry S. "What Future for the Amerindians of South America?", Minority Rights Group, London, Report no. 15, 1977, pp.31.

552. Gomez-Pompa A., Vasquez-Yanes C. "The Tropical Rain Forest : a non-renwable resource", Science 177, p.762-765.

553. Op cit note 526.

554. James B. "Greedy men are tearing out the lungs of the world", Daily Mail, London, 4 September 1980, p.20-21.

555. Op cit note 544.

556. Op cit note 541.

557. Op cit note 529, p.35.

558. INPA "Research in Progress ", INPA, Manaus, 1979, pp.35.

559. Ibid, p.4.

560. Nepomuceno E. "Destroying the World's Lung", The Guardian, London, 12 March 1979, p.19.

561. Sieniawski M. "Brazil to increase wood production drastically", Latin American Daily Post, Rio de Janeiro, 18 January 1980.

562. Op cit note 560.

563. Anon "Amazonia ja tem anteprojeto para sua preservação", Journal do Brasil, Rio de Janeiro, 25 January 1980.

564. Op cit note 541.

565. Lowe K. "The Amazon fights against man for survival", Latin American Daily Post, Rio de Janeiro, 28 November 1979, p.6-7.

566. Turner R. "Brasilia decides on intervention", Financial Times, London, 20 July 1979.

567. Whitley A. "Settlement near in crisis over Brazil project" Financial Times, London, 24 December 1981.

568. Arden J. "Ludwig's Amazon forest dream ends after S1bn investment", Financial Times, London, 8 January 1982.

569. Whitley A. "Owners of Jari minig 'kingdom' hold first meeting", Financial Times, London, 22 January 1982.

570. Goodland R.J.A. "Environmental Ranking of Amazonian

Development Projects in Brazil", from "Land People and Planning in Contemporary Amazônia", op cit note 97, p.1-26

571. Anon "Amazonia, o que ha e o que se faz", Mundo Eletrico, Ano 16, no.181, October 1974, p.8-10.

572. Llano R.G. "Energia e a Amazônia - ELETRONORTE", Revista Brasileira de Energia Eletrica, no.29, July-December 1974, p.38-43.

573. Ibid, p.38.

574. Panero R.B. "A dam across the Amazon", Science Journal, September 1969, p.56-60.

575. Panero R.B. "A South American 'Great Lakes' System", Hudson Institute Inc., New York, March 1967, pp.29.

576. Op cit note 574.

577. Op cit note 571.

578. Op cit note 572.

579. Krae P.R. "Energia no Amazônia depende de decisão politica" A Critica, Manaus, 25 January 1978, p.5.

580. Op cit note 571.

581. Op cit note 572, p.41.

582. Anon "Uma nova visão energetica da Amazônia", Mundo Eletrico Ano 15, no.179, p.8-10.

583. Anon "30 hidreletricas para a Amazônia", Mundo Eletrico, Ano 17, no.201, June 1976, p.12-14.

584. Ibid.

585. Op cit note 62

586. Anon "ELETROBRAS avalia perspectivas da bacia Amazônica", Mundo Eletrico, Ano 20, no.239, August 1979, p.22-27.

587. Op cit note 62, p.71.

588. Op cit note 199.

589. Ibid.

590. Op cit note 62, Chapter 5 "Atendimento aos sistemas isolados da Amazônia".

591. ELETRONORTE "Usina Hidreletrica de Balbina", ELETRONORTE, Brasilia, October 1979, pp.12.

592. Op cit note 63, p.2.5.

593. Anon "Tucurui : o desafio da engenharia Brasileira", Construcao Pesada, no.90, July 1978, p.22-82.

594. Op cit note 63, p.3.

595. Anon "Sistema Tucurui", ELETRONORTE, Brasilia, 1978, pp.29

596. Anon "Tucurui", Mundo Eletrico Ano 15, no.170, November 1973, p.44.

597. Anon "Tucurui", Mundo Eletrico, Ano 15, no.171, December 1973, p.38.

598. Anon "A grande usina hidreletrica", Mundo Eletrico, Ano 15, no.173, February 1974, p.36.

599. Anon "Tucurui", Mundo Eletrico, Ano 15, no.177, June 1974, p.66.

600. Anon "A intensificação dos trabalhos em Tucurui", Ano 16, no.186, March 1975, p.46.

601. Anon "Preço de energia eletrica", Mundo Eletrico, Ano 16, no.187, April 1975, p.8.

602. Anon "Tucurui", Revista Brasileira de Energia Eletrica, no.30, January-June 1975, p.2.

603. Ibid.

604. Op cit note 207.

605. Anon "Tucurui", Mundo Eletrico, Ano 16, no.189, June 1975, p.57.

606. Anon, untitled, Mundo Eletrico, Ano 17, no.195, December 1975, p.57.

607. Interview with Senior ELETRONORTE official March 1980.

608. Anon "Japanese machinery for Brazil", Water Power and Dam Construction, 1976, 28(7).

609. Anon "As hidrovias de 1^{o} classe", Mundo Eletrico, Ano 17, no.203, August 1976, p.54.

610. Op cit note 100.

611. Anon "Giesel inaugura obras de Tucurui", Mundo Eletrico, Ano 17, no.210, March 1977, p.38.

612. Finacial Times Survey "Brazil", 7 December 1982, p.V.

613. Op cit note 63, p.15-16.

614. Ibid, p.16.

615. Anon "A guarantia", Mundo Eletrico, Ano 19, no.226, July 1978, p.62.

616. Anon, untitled, Mundo Eletrico, Ano 19, no.228, September 1978, p.70.

617. Anon "Brazil exploits power potential of the Amazon", International Construction, 1978, 17(9), p.86-91.

618. Ibid, p.90.

619. Anon "As turbinas de Tucurui", Mundo Eletrico, Ano 17, no.233, February 1979, p.58.

620. Op cit note 568.

621. Anon "Projeto Trombetas : bauxita do Pará para o mundo", Commercio e Mercados, Ano XIII, no.144, p.44-48.

622. Smith D. "Oil crisis saves the dam", Financial Times, London, 3 August 1979.

623. Anon "Demanda de Carajas apressara Tucurui", Mundo Eletrico, Ano 21, no.246, March 1980, p.8.
624. Interview with senior person ELETRONORTE, March 1980.
625. Op cit note 607.
626. Interview with senior person CBA, May 1980.
627. Anon "Alcoa Brazil to build two plants", Financial Times, London, 26 June 1980.
628. Whitley A. "Brazilian fears of overcapacity grow", Financial Times Survey "Aluminium", 27 October 1982, p.17
629. Op cit note 438.
630. Interview with bargeman at Tucurui port, March 1980.
631. Interview with senior administrator, Tucurui, March 1980.
632. Ibid.
633. Op cit note 63.
634. Op cit note 395.
635. Op cit note 631.
636. Personal observation, March 1980.
637. Op cit note 631.
638. Op cit note 607.
639. Op cit note 593.
640. Op cit note 595.
641. Op cit note 607.
642. Goodland R.J.A. "Environmental Assessment - Tucurui Hydroelectric Project, Rio Tocantins", unpublished, September 1977.
643. Op cit note 16.
644. Op cit note 642.

645. Ibid.

646. Op cit note 100.

647. Ibid.

648. Ibid.

649. Op cit note 617.

650. Op cit note 595.

651. Ibid.

652. Op cit note 12

653. Ibid.

654. Oliveira S., Brito O. "So ação do Governo pode por fim a tensão social", O Globo, 11 February 1980.

655. Op cit note 100.

656. Op cit note 619.

657. Op cit note 622.

658. Smith D. "Brazil forestry plan for Amazon dam", Financial Times, London, 4 September 1979.

659. Op cit note 636.

660. Op cit note 631.

661. Op cit note 642.

662. Op cit note 97, p.95.

663. Personal communication.

664. Op cit note 607.

665. Op cit note 97.

666. Thery H. "State and Entrepreneurs in the Development of Brazilian Amazonia" from "Land, People and Planning in Contemporary Amazonia", op cit note 97, p.72-79.

667. Codigo Civil 1933, Governo Federal do Brasil, 1933.

668. Op cit note 642.

669. Op cit note 642, p.42.

670. Op cit note 97.

671. Personal Communication.

672. Op cit note 631.

673. Op cit note 642, p.63.

674. Newspaper report sent from contact in Brazil, received June 1982.

675. Op cit note 89.

676. Anon "Dez mortos na rebelião em Tucurui", Estado de Minas, 6 April 1980, p.18.

677. Ibid.

678. Anon "Rebelião de operarios nas obras de Tucurui causa mortes e prisões", Folho de São Paulo, Sao Paulo, 6 April 1980, p.8.

679. Op cit note 676.

680. Ibid.

681. Op cit note 678.

682. Op cit note 676.

683. Op cit note 678.

684. Ibid.

685. Tucurui public relations document, ELETRONORTE 1977.

686. Interview with official in ELETRONORTE's planning department, March 1980.

687. Op cit note 607.

688. Anon "Termo de Convenio" agreement between ELETRONORTE, INPA and CNPq, January 1980.

689. Leentvaar P. "Lake Brokopondo" from "Man-Made Lakes :

their problems and environmental effects, op cit note 71, p.186-196.

690. Caufield C. "Brazil, energy and the Amazon", New Scientist 28 October 1982, p.240-243.

691. Op cit note 642.

692. Ibid.

693. Op cit note 642, p.89.

694. Op cit note 100.

695. Op cit note 642.

696. Ibid, p.129

697. Op cit note 642.

698. Ibid.

699. Op cit note 658.

700. Ibid.

701. Anon "Leilão em Tucurui", Relatorio Reservado no.667, 15-21 October 1979, p.3.

702. Anon "Madeira de Tucurui vai visar tambem carvão", O Globo 11 February 1980.

703. Anon "500 milhões para explorar a madeira de Tucurui", A Folha de Tucurui, Tucurui, 7 March 1980, p.1.

704. Op cit note 686.

705. Ibid.

706. Interview with researcher INPA, March 1980.

707. Personal communication.

708. Personal communication.

709. Ibid.

710. Op cit note 707.

711. Ibid.

712. Op cit note 703.

713. Machado G. da M. "Sera refeita a limitação de Tucurui", Gazeta Mercantil, 9 May 1980.

714. Ibid.

715. Ibid.

716. Op cit note 701.

717. Op cit note 713.

718. Op cit note 690.

719. Budweg F.M.G. "Water resources and the environment - development planning in Brazil", Water Power and Dam Construction, 1983, 35(7), p.23-30.

720. de Moraes J., Salatko V.F. "Coming : 12 600 megawatts at Itaipu island", IEEE Spectrum, 1983, 20(8), p.46-52.

721. Mundin M. "Empreiteira de Tucurui não recebe ha 90 dias", Journal do Brasil, date unknown.

722. Hughes M. "Brazil's interest arrears move up to the.S2bn mark", Financial Times, London, 22 August 1983.

723. Monosowski E. "The Tucurui Experience", Water Power and Dam Construction, 1983, 35(7), p.11-14.

371. Anon "Itaipu - uma vitoria sobre o tempo", Revista do Clube de Engenharia, Ano 93, no.420, December 1979, p.8-13.

372. Andrade H. "A atual crise de energia em Sao Paulo", Engenharia, 9:1, April 1953, unumbered.

373. Op cit note 1, p.61.

374. Ibid, p.

375. Op cit note 66, p.78.

376. Op cit note 1, p.

377. Personal communication.

378. Robcock S. "Brazil : A Study in Development Progress", Lexington Books, Massachusets, 1975, p.33-37.

379. Anon "Eletrificação rural no Brasil", Mundo Eletrico, Ano 12, no.135, December 1970, p.94.

380. Op cit note 275, p.20-53.

381. Op cit note 199, p.12.

382. Anon "Energia mais caro para autoprodutores", Mundo Eletrico, Ano 18, no.210, January 1977, p.40.

383. CESP "Estado de São Paulo - analise e acompanhamento do mercado de energia eletrica dos autoprodutores", Diretoria de Distribuição, CESP, Sao Paulo, 1974, pp.20.

384. Interview with senior personnel, Votorantim May 1980.

385. Op cit note 66, p.79.

386. Ibid, p.73-74.

387. Op cit note 65, p.46.

388. Ibid, p.47.

389. Op cit note 326, p.446.

390. Op cit note 327, p.63.

391. Op cit note 379, p.8-15.

392. Bello J.M. "A History of Modern Brazil", trans. J.L Taylor Stanford University Press, California, 1966, p.349-354.

393. Anon "Sao Simão start up", Water Power and Dam Construction 1978, 30(8), p.3.

394. Op cit note 65, p.45.

395. Ibid, p.46.

396. Ibid, p.48.

397. Op cit note 66, p.98.

398. Op cit note 1, p.231.

399. Magaldi M. "Mudanca de freqüencia", Revista Brasileira de Energia Eletrica, no.12, November 1969 - March 1970, p.49-55.

400. Op cit note 59, p.18.

401. Op cit note 399, p.49-53.

402. Magaldi M., Dreher E.J. "A mudancia de frequência no estado de Rio Grande do Sul", Revista Brasileira de Energia Eletrica, no.30, January-June 1975, p.3-9.

403. Op cit note 66, p.101.

404. Anon "Electric Power Sector", ELETROBRAS, Rio de Janeiro, 1977, pp.12.

405. Op cit note 199, p.1-36.

406. Op cit note 65, p.56.

407. Op cit note 66, p.80-82, 235.

408. Op cit note 1, p.23-41.

409. Op cit note 65, p.54.

410. Op cit note 66, p.83.

411. Ibid, p.83-84.

412. Op cit note 1, p.107-108.

413. Passos G. "Servir ao Brasil e nao servir-se do Brasil", Revista Brasileira de Energia Eletrica, no.1, June 1965, p.3

414. Vargas G. "ELETROBRAS : nova diretriz economica para o estado Brasileiro", Revista Brasileira de Energia Eletrica,

no.3, November-December 1963, p.2-3.

415. Op cit note 65, p.54.

416. Op cit note 414, p.3.

417. Anon "ELETROBRAS, 15 anos. So um começo", Mundo Eletrico, Ano 18, no.213, June 1977, p.9.

418. Op cit note 414

419. Op cit note 404, p.1.

420. "Lei de Itaipu", law no.5899, 5 July 1973, published in the Diário Oficial, Brasilia.

421. FURNAS "Areas do setor eletrico sao reditribuidas", Boletim Informativo de Furnas, 8(70), January-March 1980, p.7.

422. FURNAS "Annual Report 1977", English version, FURNAS, Rio de Janeiro, 1977.

423. Ibid, p. 11

424. Op cit note 199, p.20.

425. Op cit note 229

426. Op cit note 136.

427. Ibid

428. Ibid.

429. Op cit note 199, p.20.

430. Op cit note 160.

431. Op cit note 62, p.3.3.

432. Op cit note 38.

433. Op cit note 66, p.132.

434. Op cit note 199, p.20.

435. Op cit note 329.

436. Op cit note 193, p.1.

437. Op cit note 65, p.158.

438. Op cit note 66, p.137.

439. Anon "Dias Leite instala a ELETRONORTE : Energia Eletrica na Amazonia", Revista Brasileira de Energia Eletrica, no.24 April-June 1973, p.58-61.

440. Anon "Hydro planned for Xingu river", Water Power and Dam Construction, 1978, 30(11), p. 7

441. Op cit note 199, p.20.

442. Interview with senior official of 'The Light', November 1979.

443. Lambert R. "Brazil buys out Brascan", Financial Times, London, 29 December 1978.

444. Op cit note 1, p.43-81.

445. Gibbens R., Smith D. "Departure improves dividend outlook" Financial Times, London, 30 December 1978.

446. 'The Light' "Sinopse Estatistica 1978", 'The Light', Rio de Janeiro, 1978, pp.32.

447. Op cit note 442.

448. Anon "Where to draw the line on 1978", Financial Times, London, 29 December 1978.

449. Op cit note 442.

450. Op cit note 446.

451. Anon "Estrutura da Itaipu Binacional", Construcao Pesada, Ano 9, no.98, p.20-22.

452. Op cit note 336.

453. Anon "O Tratado de Itaipu", Revista Brasileira de Energia Eletrica", no.24, April-June 1973, p.49-57.

454. Op cit note 199, p.21.

455. CEPEL "Relatorio de Atividades 1978", Centro de Pesquisas

de Energia Eletrica, Grupo ELETROBRAS, Rio de Janeiro, 1978, pp.36.

456. Op cit note 66, p.147-148.

457. CEPEL "Informe CEPEL" no.1, CEPEL, Rio de Janeiro, December 1979, pp.4.

458. Op cit note 455, p.2.

459. Op cit note 457, p.4.

460. Op cit note 199, p.

461. Op cit note 66, p.148.

462. Op cit note 160.

463. Op cit note 393.

464. Anon "Paranaiba river development", Water Power and Dam Construction, 1977, 29(11), p.7.

465. Op cit nite 65, p.80.

466. Anon "CESP : Compahia Energetica de São Paulo", Brazilian Gazette Special Supplement, Year 6, no.8, Rio de Janeiro, 1979/80, p.1-4.

467. CESP "Relatorio Tecnico de Produção e Distribuição de Energia Eletrica 1979", CESP, Sao Paulo, 1979.

468. Ibid, p.11.

469. Anon "Projeto e obras das novas hidreletricas da CESP", A Construçao São Paulo, Ano XXXII, no.1669, 4 February 1980.

470. Op cit note 62, p.2.5.

471. Op cit note 420.

472. Op cit note 136.

473. Op cit note 421.

474. Op cit note 420.

475. Op cit note 64.